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The Petrology of the Early Middle Cambrian Giles Creek and Upper Chandler Formations, Northeastern Amadeus Basin, Central Australia

James A. Deckelman

Utah State University

THE PETROLOGY OF THE EARLY MIDDLE CAMBRIAN GILES CREEK AND UPPER CHANDLER FORMATIONS, NORTHEASTERN AMADEUS BASIN, CENTRAL AUSTRALIA

by

James A. Deckelman

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ABSTRACT

The Petrology of the Early Middle Cambrian Giles Creek

and Upper Chandler Formations, Northeastern

Amadeus Basin, Central Australia

by

James A. Deckelman, Master of Science

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Major Professor: Dr. Robert Q. Oaks, Jr.
Department: Geology
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The Giles Creek and upper Chandler formations crop out in the northeastern Amadeus Basin from the north flank of Ross River syncline south to the Pillar Range, and from the nose of Ooraminna anticline east to the Simpson Desert. Twenty-four sections of the Giles Creek and nineteen sections of the upper Chandler were measured by the author in this area. The Giles Creek lies disconformably above the upper Chandler Formation and conformably below the Shannon Formation. The upper Chandler is conformably underlain by the lower Chandler throughout the area except at Ross River Gorge and Wallaby No. 1 well. There the upper Chandler overlies the Todd River Dolomite.

The Giles Creek and upper Chandler consist of interbedded carbonates, terrigenous-rich carbonates, and mudrocks. Terrigenous-rich carbonates and mudrocks comprise over half of the volume of the Giles Creek at most locations in the area.

Lime mudstones and cryptalgalaminated boundstones with domal stromatolites are common in the Giles Creek. The Phillipson and

Northern Facies of the Giles Creek are locally fossiliferous at the base. Ooids are present at the top of the Southern and Phillipson Facies of the Giles Creek at most locations. Anhydrite is present in the carbonates and mudrocks of the Giles Creek at Dingo No. 1 and Wallaby No. 1 wells. Gypsum is present in dolostones of the Giles Creek at Wallaby No. 1 well. Oncolite grainstones and boundstones, cryptalgalaminated boundstones, and birdseye-rich lime mudstones are common in the upper Chandler.

The mudrocks of the Giles Creek and upper Chandler are composed of quartz, K-feldspar, illite, muscovite, biotite, kaolinite, smectite, plagioclase, and anhydrite, with minor amounts of limonite, hematite, vermiculite, chlorite, and zircon. Calcite and dolomite cement the mudrocks. Acid-insoluble residues of the carbonates are composed of the above noncarbonate minerals, organic matter, pyrophyllite, and witherite.

The size and amount of terrigenous material in the Giles Creek increases to the west-southwest, which indicates that the terrigenous sediments were derived from a source area in that direction.

Sediments of the Giles Creek and upper Chandler were dolomitized by seepage-reflux of a hypersaline brine. Lateral and vertical variations in the amount of dolomite are inversely related to the amount of terrigenous material, and indicate that permeability of the sediments was a controlling factor in the distribution of dolomite in the Giles Creek.

Sediments of the Giles Creek and upper Chandler accumulated on shoals, in shoal-margin lagoons, on tidal flats, and in intracoastal lagoons. Shallow, open-shelf deposits are also present at the base of

the Giles Creek at Ross River Gorge. Cyclicity in the sediments of the Giles Creek was caused by lateral shifts in the position of the tidal flats and intracoastal lagoons during continual subsidence of the basin. Both the Giles Creek and upper Chandler were deposited during major regressions of the sea. Lateral relations of lithofacies in the Giles Creek indicate that the area was bounded by deeper water to the north and south during the Middle Cambrian.

Differential subsidence of the basin resulted in deposition of greater thicknesses of Giles Creek sediments in the Phillipson Pound and Ross River-Fergusson syncline areas. Differential subsidence in the Phillipson Pound area was partially offset by salt-induced growth of Ooraminna, Todd River-Windmill, Brumby, and Teresa anticlines.

Facies relations and lateral variations in thickness of the Giles Creek suggest that the amount of offset on the Rodinga and Camel Flat faults is minor, perhaps on the order of 1 to 2 kilometers at most.

Initial carbonate sediments of the Giles Creek and upper Chandler were altered by syngenetic inversion of aragonite to calcite, recrystallization of calcite, precipitation of pyrite, and replacement of calcite by dolomite; anagenetic silicification, compaction, and fracturing; and epigenetic oxidation, precipitation of calcite, dedolomitization, and silicification.

Post-depositional changes in the terrigenous sediments include syngenetic oxidation, alteration of clay minerals, precipitation of silica, and dolomitization.

(187 pages)

INTRODUCTION

General Statement

Significant thicknesses of marine sediment accumulated in the northeastern Amadeus Basin in early Middle Cambrian time. This sediment is assigned to the Giles Creek and upper Chandler formations, and forms a part of the Pertaoorrta Group. A detailed petrologic study of the Giles Creek and upper Chandler was conducted in the area southeast of Alice Springs, Northern Territory. Both formations are well exposed and easily accessible throughout the area. They are penetrated by four exploratory wells and are expressed in seismic data acquired in the southern and western parts of the study area.

Apart from studies by J. W. Keith (1974) and the Bureau of Mineral Resources (BMR), no detailed work has been done on these formations in the study area. Because the units are potential reservoirs for hydrocarbons and directly overlie potential source rocks in the lower Chandler, a comprehensive study of these units has direct economic applications.

Purpose of Investigation

This study was conducted to determine the petrology of the Giles Creek and upper Chandler formations, and to determine the structural evolution of the area during Middle Cambrian and post-Cambrian time. Specific objectives were to:

1. Locate and measure sections of the Giles Creek and upper Chandler at the axes and on the flanks of major anticlines in the Phillipson thrust sheet, and on opposite sides of major thrust faults throughout the area.

2. Subdivide the formations into mappable lithofacies.

3. Determine if depositional thinning of the units occurred over the crests of anticlines.

4. Estimate the amount of offset on major faults using thickness data and facies relationships.

5. Determine original carbonate-grain types and abundances, non-carbonate mineralogy, and the diagenetic history of the sediments.

6. Determine the environment of deposition of the sediments.

7. Determine the paleogeographic setting of the area during upper Chandler and Giles Creek time.

Location and Accessibility

The study was conducted over a 25,000 km^2 area of the Amadeus Basin. The area lies south and east of Alice Springs, Northern Territory, between 23°30' and 24°45' south latitude, and 133°45' and 135°20' east longitude (Figures 1 and 2). The area is bounded by the MacDonnell and Fergusson ranges to the north, the Pillar Range to the south, the Simpson Desert to the southeast, and the James Ranges to the west (Figure 2). It is located in the northeastern part of the Amadeus Basin, adjacent to the present northern margin of the basin at the Arunta Complex (Figures 1 and 2). The geology of the area is shown on the BMR Alice Springs, Illogwa Creek, Rodinga, and Hale River 1:250,000 Geological Series sheets, (Wells et al., 1967). Most of Oil Permit 189 and parts of Oil Permits 175 and 178 are within the study area.

Access to most of the area is good. Two-lane graded roads connect Alice Springs with Ross River Homestead, Ringwood Homestead, and Santa Teresa aboriginal settlement (Figure 3). These roads provide easy access to northern, eastern, and central parts of the study area. One-lane tracks connect these areas with Allambi, Deep Well, Todd River, and Andado homesteads. Access to those areas south of Allambi has been temporarily improved by seismic lines cut for the Camel Flat survey. Sparse vegetation, infrequent rainfall, and wide alluvial areas with low relief enhance accessibility to off-track areas in the north. These areas are easily accessible by four-wheel drive vehicles, except after heavy summer rains. Longitudinal sand dunes, hummocky topography, and a dense Spinifex cover considerably reduce accessibility to outcrops in the south. Reconnaissance by helicopter is efficient and cost-effective in these areas.

Climate and Vegetation

The area of study is arid. Rainfall is infrequent, extremely irregular, and inadequate to support large-scale agriculture. The average monthly rainfall increases from south to north, and is commonly greater in summer than in winter (Wells et al., 1967). Relative humidity in the area is extremely low, also reaching average maximums in the summer and minimums in the winter. Diurnal and seasonal fluctuations in temperature are extreme. Summer maximum temperatures commonly exceed 100°F, with evening lows only in the 60's.

Floral communities in the area are typical of most arid regions in central Australia. Low-woodland communities of mulga, gidgae, myall, bloodwood, and drought-evading grasses and forbes are extensive in alluvial areas. Sandstones typically host low scrub associations of the native fuschia bush and the native fig, with an upperstory of isolated ghost gums and white cyprus pine. Spinifex is present throughout the area, and shows a pronounced affinity for carbonate substrates and north-facing slopes. Spinifex-covered dune fields are common in the south, and often contain stands of the desert oak Casuarina. Ephemeral grasses and the red river gum, Eucalyptus camaldulensis, frequently dominate riverine communities in the area.

Field Methods

Field work was conducted during June, July, and August of 1980, and June of 1981. Twenty-four sections of the Giles Creek and nineteen sections of the upper Chandler were measured by the author (Figure 3; Table 1). Sections B, C, E, G, H, I, J, K, and L were measured and described in detail. Data recorded in description of these sections included bedding thickness and character; mineralogy; lithology; fresh and weathered colors; grain or crystal size; synoptic relief, character, and type of organic sedimentary structures; weathering character; carbonate-grain types; extent and type of silica replacement; fossil content and abundance; odor; and character and abundance of inorganic sedimentary structures. Each bed was individually described. Other sections were measured to determine lateral variations in thickness, pronounced changes in facies, ratios of dolostone to total carbonate, and percent terrigenous material. Thicknesses of the upper Chandler and each unit of the Giles Creek were recorded at these sections. Steep dips were encountered at sections D, O, P, Q, W, and X. These sections were measured with a Brunton compass and a fifty-meter tape. Other sections were measured with a 1.5 meter staff, Brunton compass, and Abney level.

Aerial photographs and geologic maps were used to select locations of measured sections. Sections in the Phillipson thrust sheet (Figure 4) were measured at the axes and on the flanks of major anticlines to determine if stratigraphic thinning occurs over the crests of these structures. Sections in the N'Dhala thrust sheet were measured on the south flank of Ross River and Fergusson synclines, and southeast of Gaylad syncline. These sections enhance thickness control along the south margin of the thrust sheet, and provide information on northward facies change in the Giles Creek and upper Chandler. Sections along the north flank of Camel Flat syncline provide east-west thickness control south of the Phillipson thrust sheet. Sections in the Rodinga Ranges are useful in estimating the amount of horizontal offset on the Rodinga fault, and provide information on southward facies change in the Giles Creek and upper Chandler.

The thickness of the Giles Creek and upper Chandler at sections 1, 2, 3, 5, 6, 7, 8, 9, and 10 was interpreted from sections measured by the BMR (Wells et al., 1967). Sections 1, 2, 5, 6, 7, 8 and 10 were subsequently traversed in the field to pick formation contacts consistent with those defined in this report.

The tops of sections V and Q could not be measured because of complex faulting. Only minimum thicknesses are available for the Giles Creek at these two locations.

One hundred and two samples of the Giles Creek and upper Chandler were collected in the field. Most samples were collected from the proposed reference section for the Giles Creek at Ulta Bank Creek. Samples were not collected at regularly spaced intervals. Carbonate samples were collected from surface outcrop, and mudrock samples were collected from 1 to 2 feet below the surface.

Laboratory Methods

Fifty-four samples from the upper Chandler and Giles Creek were retained for analysis in the laboratory.

Analysis of acid-insoluble residues was conducted on all carbonate samples. These samples were crushed with a hydraulic press and a steel mortar and pestle. Crushed samples were powdered in a Bico Type UA pulverizer. Twenty-five grams of powdered sample were used for each analysis. One hundred to one-hundred fifty ml of 10% (by volume) hydrochloric acid solution were required to dissolve the carbonate in most samples. Excess acid was removed by decanting. Insoluble residues were then washed with deionized water, dried in a single-wall Transite oven at 60°C, and weighed.

The amount of organic material in each sample was determined by measuring weight loss due to oxidation in a sodium hypochlorite solution. One hundred ml of 5.25% (by weight) sodium hypochlorite solution was added to the insoluble residue of each sample. The sodium hypochlorite solution was decanted after 48 hours. The unoxidized residue was then washed with deionized water, dried in a single-wall Transite oven at 60°C, and weighed. Suspended fines in samples 2, 18, and 19 were flocculated by adding small amounts of 1N calcium chloride solution. Because weight loss was anomalously small for these samples only, it is likely that calcium chloride precipitated from solution, and/or calcium ions adsorbed onto clay minerals. For this reason, data on weight percent organic matter were omitted for these samples.

The mineralogy of carbonate and mudrock samples was determined by X-ray diffraction. Whole-rock samples were used for mudrocks, and acid-insoluble residues were used for carbonates. Whole-rock samples were powered in a Bico Type UA pulverizer, and oriented grain mounts were prepared from that fraction of sample which would penetrate a 115-mesh sieve. Samples were scanned from 2° 2θ to 35° 2θ on a Siemens Krystalloflex IV X-ray diffractometer. Smectite-group minerals were distinquished from other minerals having a major peak at 6.0° 2θ by glycolation (Carroll, 1970). Samples having a major peak at 12.4° 2θ were then heated in a muffle furnace at 550°C for one hour to enhance distinction of kaolinite from chlorite on X-ray diffractograms. Diffraction peaks were identified using indices prepared by Chen (1977) and Berry (1974).

Thin sections from samples of 27 carbonates, two cherts, and one mudrock were prepared by Roberts Petrographic Section Service of Monterey Park, California. Thin Section No. 209 was prepared by the author. One half of each thin section was stained with Alizarin Red-S to distinguish calcite from dolomite. Sample 76 was impregnated with epoxy prior to sectioning. All thin sections were cut perpendicular to bedding, except No. 47, which was cut 45° to bedding, and No. 50, which was cut 60° to bedding. Data recorded in petrographic descriptions included lithology, abundance and type of terrigenous material, depositional texture, carbonate-grain type and abundance, crystal size, abundance and type of organic and inorganic sedimentary structures, degree of recrystallization or dolomitization, and an inferred sequence of diagenetic events. A magnesium oxide diffuser (Delgado, 1977) was used to aid in identification of features obscured by recrystallization or dolomitization. Crystal size was measured with an eyepiece micrometer. Opaque oxide minerals were identified in reflected light.

A binocular microscope was used to identify minerals, classify mudrocks, and to examine polished thin-section offcuts.

Rock-Name Terminology

The Giles Creek and upper Chandler are composed of limestone, dolostone, and mudrocks, with minor amounts of chert and sandstone. Detailed rock names of samples selected for study in the laboratory are listed in Tables 2 and 3.

A limestone is a sedimentary rock composed chiefly of carbonate, of which more than 50% by weight or areal percentage under the microscope is calcite, with or without magnesium carbonate.

In this report "dolomite" is used only as a mineral name, and the term dolostone is used to describe a sedimentary rock composed chiefly of carbonate, of which more than 50% by weight or areal percentage under the microscope is dolomite.

A mudrock is a fissile or nonfissile lithified sediment containing substantial amounts of [terrigenous] silt, clay, or mixtures of the two (Blatt et al., 1980, p. 381). Here the term is restricted to those rocks containing more than 50% (by weight) clay, silt, or mixtures of the two.

A sandstone is here defined as a sedimentary rock composed of more than 50% sand-sized terrigenous fragments and less than 25% gravel, which may or may not contain silt- or clay-sized matrix.

Gary et al. (1972, p. 122) defined chert as: "A hard, extremely dense or compact, dull to semi-vitreous, crypto-crystalline sedimentary rock consisting dominantly of crypto-crystalline silica (chiefly fibrous chalcedony) with lesser amounts of micro- or crypto-crystalline quartz and amorphous silica (opal); it sometimes contains impurities such as calcite, iron oxide, and the remains of siliceous and other organisms."

The term dolocalcrete is used here to describe a dolomite-replaced rock formed by the epigenetic accumulation of calcium carbonate in unconsolidated sediments under soil-forming conditions in dry climates.

Dunham's (1962, p. 117) classification of carbonate rocks (Table 4) is used to describe the depositional texture of limestone and dolostone. Fresh color; crystal size; grain type and abundance; carbonate composition; organic and inorganic sedimentary structure; mineralogy, size, and abundance of terrigenous material; and degree of textural alteration are included in rock names as modifiers of depositional texture.

Rock colors are determined by comparison with standards listed in the rock color chart of Goddard (1963). Colors in the chart are described using the Munsell system of color indentification.

Friedman (1965, p. 653) described carbonate rocks having crystals with a diameter of 100-250 microns as fine crystalline, those having crystals with a diameter of 250-500 microns as medium crystalline, and those having crystals with a diameter of 500-1000 microns as coarse crystalline. Crystals having a diameter smaller than 100 microns are here defined as very fine, and those with a diameter larger than 1000 microns are here defined as very coarse.

Pellets are small spherical, elliptical, ovoid, or irregularly shaped clasts, typically devoid of internal structure, and possibly of fecal origin. In this report, the term oolite is used synonymously with the term ooid. Oolites are defined as: "... spherical or ellipsoidal particles, [generally] smaller than 2 mm in diameter, typically composed of calcium carbonate, and having a central nucleus surrounded by a rim consisting of more than one layer, that displays concentric or radial fabric" (Friedman and Sanders, 1978, p. 567). Calcispheres are originally hollow calcareous spherical bodies with well defined walls (often composed of several layers), usually measuring 75 to 200 microns in diameter, some having radially arranged spines on their outer surface (Wray, 1977, p. 103). Intraclasts are "... fragments of penecontemporaneous, usually weakly consolidated [or cohesive] carbonate sediment that have been eroded from adjoining parts of the sea bottom and redeposited to form a new sediment" (Folk, 1959, p. 4). Algal intraclasts are those intraclasts composed of algal-bound sediment, and mud intraclasts are those intraclasts composed of partly indurated carbonate mud. Carbonate grains comprising less than 10% of the volume of the rock are modified by the suffix "-bearing", and those comprising more than 10% of the volume of the rock are modified by the suffix "-rich."

Calcite-dolomite mixtures in carbonate rocks are described using the terminology of Pettijohn (1975, p. 360). The depositional texture of the rock is modified by the term "lime" if the carbonate present consists of more than 90% calcite, by the term "dolomitic lime" it the carbonate present consists of 50% to 90% calcite, by "dolomite" if the carbonate present consists of more than 90% dolomite, and by "calcitic dolomite" if the carbonate present consists of 50% to 90% dolomite.

Silt-size terrigenous constituents are those which have diameters between 1/256 mm and 1/16 mm, and sand-size terrigenous constituents are those which have diameters between 1/16 mm and 2 mm (Wentworth, 1922, p. 381). Silt- or sand-bearing carbonates are those in which the volume of terrigenous material is less than 10% of the rock, and silty or sandy carbonates are those in which terrigenous material constitutes 10% to 50% of the volume of the rock.

Terminology from Powers' (1962, p. 150) classification of carbonate rocks (Table 5) is used to describe the degree of textural alteration in recrystallized and replaced carbonates with relict texture. Terms describing the degree of textural alteration are appended to carbonate rock names.

Mudrocks are classified according to the scheme of Blatt et al. (1980, p. 382) shown in Table 6. Mudrock samples having X-ray diffraction patterns with a well-developed peak for dolomite are termed "dolomitic", and those with a well-developed peak for calcite are termed "calcitic."

Chert names include the color (fresh) of the rock, and a description of relict texture and structure, where discernable.

Terminology of Sedimentary Structures

Organic Sedimentary Structures

"Cryptalgal sedimentary rocks or rock structures are those which have originated through the sediment-binding and/or carbonate-precipitating activities of nonskeletal algae" (Aitken, 1967, p. 1163). Cryptalgalaminae are "discontinuous, more or less planar [to wavy parallel] laminae believed to have resulted from the activities upon and within the sediments of successive mats or films of blue-green or green algae" (Aitken, 1967, p. 1164). An algal stromatolite is a "... fixed body of cryptalgal origin, characterized by non-planar lamination and possessing definable boundaries or contacts with other stromatolites" (Aitken, 1967, p. 1163). The relief of an algal stromatolite above its substrate at an instant in time during its formation is defined as the synoptic relief of the algal stromatolite (Walter, 1976, p. 691). A domal stromatolite is a "... simple or compound blister- to beehive-shaped algal stromatolite of low relief" (Aitken, 1967, p. 1166). A columnar stromatolite is an algal stromatolite "... consisting fundamentally of nonlinked, vertically stacked, high arched [cylindrical or club-shaped] hemispheroids or paraboloids ..." (Aitken, 1967, p. 1168). A thrombolite is a cryptalgal structure characterized by a macroscopic clotted fabric which contains little or no internal lamination (Aitken, 1967, p. 1164). An oncolite is an unattached, regularly or irregularly spheroidal, concentrically to semi-concentrically laminated body of cryptalgal origin (Aitken, 1967, p. 1163).

Collenia is here regarded as a form genus of domal stromatolite composed of algal laminae which tuck under at the base, imparting a cauliflower-like shape to the stromatolite in profile and nearly circular shape to the stomatolite in plan.

Walter (1976, p. 687) defined a biostrome as a stratiform organo-sedimentary structure having a minimum width which is more than one hundred times its maximum thickness. A stratiform sheet biostrome is a biostrome which is composed entirely of flat continuous cryptalgalaminae, and a domal biostrome is a biostrome which contains abundant domal stromatolites.

Small domal stromatolites are those which are less than 5 cm in diameter, medium domal stromatolites are those which are 5 cm to 20 cm in diameter, large domal stromatolites are those which are 20 cm to 80 cm in diameter, and very large domal stromatolites are those which are greater than 80 cm in diameter.

Logan et al. (1965) referred to domes as "hemispheroids", and described their lateral relations in terms of two modes. Mode LLH-C hemispheroids are those laterally linked hemispheroids which are separated by a space smaller than the diameter of the stromatolite, and mode LLH-S hemispheroids are those laterally linked hemispheroids which are separated by a space greater than the diameter of the stromatolite.

Inorganic Sed imentary Structures

A bed is a layer of sedimentary rocks or sediment which is bounded above and below by bedding surfaces representing cessation of deposition, abrupt change in depositional conditions, and/or erosion (Campbell, 1967, p. 12).

Those sediments or sedimentary rocks having beds less than 0.2 meter thick are here defined as thin-bedded, those having beds which are 0.2 meter to 0.5 meter thick are defined as medium-bedded, those having beds which are 0.5 meter to 1.0 meter are defined as thick-bedded, and those having beds which are greater than 1.0 meter thick are here defined as very thick-bedded.

Massive beds are here defined as those beds greater than one meter thick which are nearly structureless in outcrop.

Birdseye structures are irregular tubes of sparry calcite which fill former voids in limestones and dolostones (adapted from Gary et al., 1972, p. 76).

Carbonate rocks having fine, narrow, elongate, unsupported voids aligned parallel with lamination are said to have fine laminoid fenestral fabric (Logan, 1974, p. 214).

A mud crack is a downward-wedging "... fracture [with] a crudely polygonal pattern [in plan view], formed by the shrinkage of clay, silt, or mud in the course of drying under the influence of atmospheric surface conditions" (adapted from Gary et al., 1972, p. 468).

PREVIOUS INVESTIGATIONS

The late 1800's marked the advent of geological investigation in the Amadeus Basin. Initial studies were sporadic and largely unrelated. Chewings' (1886) investigation of the source of the Finke River stands as the earliest geological study in the area. In later years, East (1889) reported on the Arunta Complex, the Heavitree Quartzite, and the Bitter Springs Formation, and Brown (1890) recognized a major nonconformity in the area near Paddys Hole Creek and south of the Hale River.

Paleontological studies also initiated in the late 1800's. Brown, Thornton, and Etheridge (Brown, 1897; Etheridge, 1892) studied invertebrate fossils from the area near Tempe Downs, and Ordovician fauna were collected from the Larapinta Group along the Finke River (Tate, 1896).

Prospecting for gold also accelerated at the turn of the century. Gold was discovered in the Heavitree Quartzite at White Range in 1897 and south of Winnecke Depot in 1902 (Brown, 1902, 1903). A large number of prospecting expeditions were launched in the years to follow (Wells, 1904; Wells and George, 1904; Basedow, 1905; George and Murray, 1907).

Since that time the Amadeus Basin has attracted the interest of many geologists. Mawson and Madigan (1930), Chewings (1928, 1931, 1935), and Madigan (1932a, 1932b, 1933, 1938, 1944) studied stratigraphy of the MacDonnell Ranges in the 1920's, 1930's, and 1940's, and the BMR conducted the first regional studies in the 1950's and 1960's (Wells et al., 1967, 1970). Countless studies have been conducted in recent years by petroleum exploration and mining firms, the Northern Territory Department of Mines and Energy, and the BMR.

The Giles Creek and upper Chandler formations have not been studied in detail. The BMR measured and described these formations at ten locations in the area (Table 1), and included short descriptions of these formations in Bulletin 100 (Wells et al., 1970), Report 113 (Wells et al., 1967) and in the explanatory notes of the Hale River, Illogwa Creek, Alice Springs, and Rodinga 1:250,000 sheets. Sections at Ross River Gorge and West Todd River were also measured and described by Keith (1974).

GENERAL GEOLOGIC SETTING

Stratigraphy

The Amadeus Basin is an 800-kilometer-long, east-west trending intracratonic depression. The basin spans 150,000 square kilometers of the southern part of the Northern Territory and the eastern part of Western Australia (Figure 1). It is bounded to the north by the Precambrian Arunta Complex, and by the Musgrave-Mann Complex and the Olia Gneiss to the south. Over 15,000 meters of Proterozoic, Cambrian, Ordovician, Silurian, Devonian, Permian, Jurassic, Cretaceous, Tertiary, and Quaternary deposits are preserved in the basin (Figure 5).

In the northeastern Amadeus Basin, Precambrian basement rocks are unconformably overlain by the Heavitree Quartzite. Conformably above the Heavitree lies the Bitter Springs Formation, a Proterozoic sequence of carbonates, shale, sandstone, and evaporites. The Areyonga Formation lies disconformably above the Bitter Springs, and is composed of dolostone, siltstone, sandstone, and proglacial conglomerate. The Areyonga is conformably overlain by shallow-marine carbonates, terrigenous clastics, tidal and fluvial sands, and proglacial sediments of the Pertatataka Formation. Wells et al. (1967) divided the Pertatataka into the Ringwood, Limbla, Olympic, Waldo Pedlar, Pioneer, Cyclops, and Julie members. More recently, Preiss et al. (1978) proposed elevation of the Olympic and Julie members to formation status, and inclusion of the Ringwood and Limbla members in the Aralka Formation.

Sediments of the Pertaoorrta Group rest conformably on the Pertatataka Formation. The Pertaoorrta Group is composed of deltaic sandstone, siltstone, and mudshale of the Arumbera Sandstone (Conrad, 1981), fossiliferous dolostone, shale, and sandstone of the Todd River Dolomite, evaporites, carbonates, chert, and mudrocks of the Chandler Formation, and marine carbonates, mudrocks, and sandstone of the Giles Creek, Shannon, and Goyder formations. Sediments of the Pertaoorrta Group are Late Proterozoic to Late Cambrian in age.

The Pertaoorrta Group is overlain by Late Cambrian and Ordovician sediments of the Larapinta Group. The Larapinta Group consists of the Pacoota, Horn Valley, Stairway, Stokes, and Carmichael formations. The Pacoota and Stairway sandstones are the principal reservoir rocks at the Mereenie and Palm Valley fields. The Horn Valley is the probable source for hydrocarbons reservoired at these fields.

Unconformably above Larapinta Group sediments lies the Mereenie Sandstone, a Siluro-Devonian unit which accumulated in shallow-marine, fluvial, and eolian environments. The Pertnjara Group rests unconformably above the Mereenie, and is composed of Devonian lacustrine siltstone and terrigenous molasse deposits. The Pertnjara Group consists of the Parke Siltstone, the Hermannsburg Sandstone, and the Brewer Conglomerate.

Permian, Jurassic, and Cretaceous sediments were deposited locally in the basin. These sediments accumulated in marine, fluvial, and fluvioglacial environments (Wells et al., 1970). Tertiary fluvial, lacustrine, and silcrete deposits lie unconformably on older sediments throughout the area.

Structure

Two periods of diastrophism were responsible for the formation of a depression parallel to the present trend of the basin (Wells et al., 1970). The first event was the Areyonga Movement, a post-Bitter Springs movement which lifted areas in the southern part of the basin, and areas north of the present basin margin. These areas were also lifted by a later Proterozoic event, the Souths Range Movement. The areas uplifted by these movements became the main source for Proterozoic terrigenous deposits in the north.

A third Proterozoic event may have formed the Central Ridge, an east-west trending structural high which developed in the north-central part of the basin (Figure 4). The final pulse of Proterozoic deformation was the Petermann Ranges Orogeny, an event which folded and uplifted a large area in the southwest. Uplift of this area provided a source for younger Proterozoic and Cambrian terrigenous sediments in the north.

In Silurian time, the Amadeus Basin experienced a series of broad vertical movements collectively called the Rodingan Movement. During this time, as much as 3,000 meters of Cambro-Ordovician section was removed from the northeastern part of the basin. Movements in the Early Devonian were centered in the northern part of the basin, and involved successive uplifts of a block of Precambrian, Proterozoic, and Cambrian rocks (Wells et al., 1970). These events are assigned to the Pertnjara Movement. The final stage of deformation was the Late Devonian Alice Springs Orogeny. Deformation in this orogeny led to the development of folds, thrust sheets, and nappe complexes (Wells et al., 1970). Except for tilting and minor faulting, the Amadeus Basin stabilized after the Alice Springs Orogeny.

Detailed geologic maps of the northeastern Amadeus Basin by

R.Q. Oaks, Jr. indicate that the area is structurally complex. Oaks (oral communications, 1981, 1982) reported surfaces of decollement at numerous stratigraphic horizons, north-south strike-slip faulting, and considerable displacement of thrust sheets northward and southward toward the Central Ridge (Figure 4).

STRATIGRAPHIC UNITS UNDERLYING THE UPPER CHANDLER FORMATION

General Statement

The upper Chandler lies conformably above the lower Chandler throughout the area except along the north flank of Ross River syncline and at Wallaby No. 1 well. There the upper Chandler lies unconformably above the Todd River Dolomite.

Lower Chandler Formation

The name Chandler Limestone was first proposed by Ranford et al. (1965). Because of its variable lithology, it is here proposed that the name Chandler Formation be used in place of Chandler Limestone. Informal division of the Chandler into upper and lower units was suggested by Oaks (oral communication, 1980). The lower unit of the Chandler is herein referred to as the "lower Chandler", and the upper unit of the Chandler is herein referred to as the "upper Chandler." The type area of the Chandler is 10 km northeast of Tempe Downs homestead.

The lower Chandler is present at most locations in the area. It is absent depositionally only along the north flank of Ross River syncline. The lower Chandler rests conformably on the Todd River Dolomite in most areas. Conrad (1981) reported that the Chandler disconformably overlies the Arumbera at the Bloodwood and BMR Deep Well sections, and locally along the west side of Todd River anticline (Figures 2 and 3). The lower Chandler is conformably overlain by the upper Chandler throughout the area except at Dingo No. 1 Well. There the lower Chandler lies beneath the Giles Creek Formation.

The lower Chandler is composed of medium-bedded gray and black fetid limestone and dolostone, with interbeds of evaporites and red shale and siltstone. Although Oaks (oral communication, 1981) reported the presence of gypsum at Ulta Bank Creek, evaporites are generally not exposed in outcrop. Laminated chert is abundant in the carbonates. Green and red siltstone and shale are present at the base of the Chandler in some areas. These beds are regarded as basal Chandler in the BMR Rodinga 1A well (Felton, 1981), but are regarded by Oaks (oral communication, 1982) as upper Todd River because they contain pink fossiliferous dolostone east of Marian Waterhole. The unit is characteristically deformed, and individual beds are commonly contorted.

Trilobites were found in the lower Chandler on the north flank of Teresa anticline by Oaks, and hyolithids (?) were found in the western Purple Hills by Oaks and the author. Wells et al. (1967) tentatively regarded the unit as Lower Cambrian.

The contact between the upper and lower Chandler is sharp. The contact is frequently marked by a band of white nodular chert one to three meters thick. The white chert is laterally continuous and consistently occurs at the same stratigraphic horizon. Field lithological logs from BMR Rodinga 1A well (Felton, 1981) indicate that the marker is less pronounced at depth. The white chert marker is present throughout the Phillipson thrust sheet except at sections A and 10. It is present at sections N, S, W, and X in the Camel Flat thrust sheet, but present only at section O in the Rodinga thrust sheet. It is missing entirely at sections in the N'Dahla thrust sheet. Where the white chert marker is absent, the contact is placed at the base of the shale immediately below the lowermost thick-bedded, olive gray-weathering, pitted carbonate of the upper Chandler.

Todd River Dolomite

The Todd River Dolomite was named and defined by Wells et al. (1967). Conrad (1981) redefined the transitional sandstone beds at the base of the Todd River as Unit 4B of the Arumbera Sandstone. The type section is located at Ross River Gorge, and the name was derived from the Todd River.

The Todd River Dolomite crops out on both flanks of Ross River, Fergusson, and Gaylad synclines; around Phillipson Pound and Ooraminna anticline; on the west flank of Todd River anticline; on the north flank of Teresa anticline; in the Purple Hills; and northeast of Centenary Dam. It is underlain by the Arumbera Sandstone throughout the area.

The Todd River is composed of pink, brown, and gray thick-bedded dolostone and calcareous siltstone and shale. The dolostone is glauconitic, fossiliferous, and locally cross-laminated and oolitic. Archaeocyathids and brachiopods are abundant.

Joyce Gilbert-Tomlinson, formerly of the BMR, provisionally dated the formation as Early Cambrian on the basis of the brachiopod "Micromitra" etheridgei, a species which is also known from the Early Cambrian of South Australia.

The upper unit of the Chandler is disconformably underlain by the Todd River Dolomite near Ross River Gorge. Here the contact is placed at the top of the cliff-forming, thick-bedded, archaeocyathid-rich pink dolostone. The upper Chandler is also underlain by the Todd River at Wallaby No. 1 well. There the contact may also be disconformable.

STRATIGRAPHIC UNITS OVERLYING THE GILES CREEK FORMATION

Shannon Formation

The Shannon was originally defined and named by Wells et al. (1967). The name was derived from Shannon Bore, located eight miles south of the type section at Ross River Gorge.

The Shannon is composed of interbedded red, brown, and purple shale and siltstone, and pink and gray limestone and dolostone. The carbonates contain intraformational breccia, thrombolites, Collenia, and columnar and domal stromatolites. They are locally oolitic, cross-laminated, and cherty. A thick interval of red shale is present at the base of most sections. The interval is recessive and forms wide strike valleys. Thin sands are present in the upper part of the Shannon in some areas. Fossils were found in carbonates near the base of the unit at the East Desert Bore section.

The Shannon conformably overlies the Giles Creek throughout the area. The contact of the Giles Creek with the Shannon is covered in most areas south of Ross River Gorge. It is sharp where exposed. The contact is placed at the top of the uppermost carbonate in the Giles Creek below the thick recessive basal shale unit of the Shannon. The basal shale unit lies directly below the lowermost thrombolitic carbonate. This unit is present at all sections in the Phillipson thrust sheet, and present but thin at sections in the Camel Flat and Rodinga thrust sheets. It is absent at sections in the N'Dhala thrust sheet. There the contact is placed at the base of the shale interbed below the lowermost thrombolitic carbonate.

Wells et al. (1967) indicated that the Shannon is probably Middle to Upper Cambrian in age.

Hugh River Shale

The Hugh River Shale was originally named by Prichard and Quinlan (1962). The unit crops out west of the study area between Jay Creek and Alice Springs, where it overlies both the Arumbera Sandstone and the Giles Creek Formation. It is overlain by the upper Shannon Formation. A type section for the Hugh River has not been assigned.

The unit was described by Wells et al. (1967, p. 41) as follows:

> "The bulk of the unit is probably composed of red-brown or grey-brown siltstone and shale. The lowest 100 feet consists of red-brown poorly bedded and slightly micaceous siltstone, with a few interbeds of grey chert. The next 100 feet comprise interbedded yellow calcareous dolomite, shale, siltstone, and minor sandstone. Nodules of chert are present in the dolomite, and concretions of limonite, up to 12 inches across, are present in the dolomite in the lower part of the formation."

Wells et al. (1967) tentatively dated the Hugh River as early Middle Cambrian because of its position between the Arumbera Sandstone and the "Jay Creek Limestone" (upper Shannon Formation). Micropaleontologic evidence, however, suggests that the Hugh River may extend into the late Middle Cambrian. John Gorter (oral communication, 1981) correlated microfossils at the top of the Hugh River with those at the top of the basal shale unit of the Shannon, and suggested that the top of these two units may be approximate time equivalents.

STRATIGRAPHY

Upper Chandler Formation

Definition

The upper Chandler Formation is here defined as the sequence of thick- to very thick-bedded yellowish brown, yellowish orange, and gray limestone and dolostone, and white, grayish yellow, and grayish red shale and siltstone which overlie the dark fetid cherty carbonates, red and green mudrocks, and evaporites of the contorted lower Chandler. The carbonates form prominent strike ridges, and are typically massive, rough-weathering, cryptalgalaminated, locally vuggy and glauconitic, and rich in oncolites. In the Phillipson Pound and Teresa anticline areas, they are overlain by other carbonates which are thinner bedded, cryptalgalaminated, burrowed, locally cherty and fetid, and contain small to very large domal stromatolites, birdseye structures, pseudomorphs after gypsum, and algal intraclasts. The upper Chandler is not contorted and does not contain bedded evaporites in the subsurface.

Russell B. Shaw of the BMR (oral communication, 1981) indicated that this unit was regarded as lower Giles Creek in the original mapping of the basin. In this report, the unit is regarded as part of the Chandler Formation because it is disconformably overlain by the Giles Creek Formation. A disconformity is inferred at this horizon because the same lithofacies of the upper Chandler is overlain by different lithofacies of the Giles Creek at different locations in the area (Figures 9 and 10). Both the Giles Creek and upper Chandler are dominantly regressive sequences, and were probably separated by a period of nondeposition during a rapid advance of the sea (see HISTORY

OF SEDIMENTATION).

This unit is also regarded as part of the Chandler Formation because it lies below the base of the Giles Creek as defined by Wells et al. (1967, p. 39). In the original definition, the base of the Giles Creek is placed at "... the lowermost siltstone and shale associated with the limestone and dolomite ...", and it is stated that the Giles Creek is separated from overlying and underlying units by strike valleys. Although beds of siltstone and shale lie below the lowermost carbonate of the upper Chandler, these beds do not form strike valleys and are not as thick or as topographically well expressed as the recessive unit at the base of the Giles Creek. In fact, at some locations, the lowermost siltstone or shale of the upper Chandler is less than one meter thick.

Name

Oaks (oral communication, 1980) was first to suggest that the Chandler be divided into upper and lower units. This was done to enhance mappability of the formation, and to distinguish between its lithologically distinct upper and lower units.

Type Section

A type section has not been assigned for the Chandler Formation. It is here proposed that the reference section for the upper Chandler be located at Surprise anticline (Section I). Access to this section is excellent, the unit is well exposed, and marker horizons A and B are both present.

Age

Wells et al. (1967) tentatively regarded the Chandler as Early Cambrian. Fossils were found by the author in the upper Chandler in the Purple Hills and at the Phillipson syncline section. Wells (oral communication, 1980) stated that the fossils are similar to Cambrian hyolithids (including Bioconulites), and indicated that the alga Girvanella may also be present.

Distribution

The upper Chandler is present throughout the study area. It is exposed in the same areas and has the same lateral distribution as the Giles Creek Formation (Figure 2). It is thickest along the east side of Phillipson Pound and the crest of Teresa anticline, and thins to the north and south.

Basal Contact

The base of the upper Chandler is placed at the white chert marker (see Marker Horizons). The contact with the lower Chandler is discussed under STRATIGRAPHIC UNITS UNDERLYING THE UPPER CHANDLER FORMATION.

Giles Creek Formation

Definition

The Giles Creek Formation is here defined as the sequence of light brown and light gray limestone and dolostone, variegated shale and siltstone, and minor sandstone which disconformably overlies the upper Chandler Formation and is conformably overlain by the Shannon Formation. The carbonates are locally oolitic, cross-laminated, and cherty, and contain cryptalgalaminae, small to very large domal stromatolites, columnar stromatolites, Collenia domes, algal- and lime-mud intraclasts, mud cracks, pellets, calcispheres, halite molds, and pseudomorphs after anhydrite. A thick, recessive, locally fossiliferous interval is present at the base of all sections. The carbonates become increasingly oolitic southward. On the south margin of the N'Dhala thrust sheet, carbonates at the base are very thick-bedded and rich in oncolites. On the north margin of that thrust sheet, the formation contains dark gray fossiliferous fetid limestone and grayish green siltstone near the base, and oncolitic, oolitic, and cryptalgalaminated cliff-forming light brown dolostone near the top.

Name

The Giles Creek Formation was originally named and defined by Wells et al. (1967). It is here proposed to change the name "Giles Creek Dolomite" to "Giles Creek Formation" because dolostone comprises less than half of the carbonate in outcrop at several locations (Figure 22), and because terrigenous rocks and terrigenous-rich carbonate rocks comprise greater than half of the formation at many locations (Figure 7). The name was derived from Giles Creek, located 87 kilometers east of Alice Springs.

Type Section

The type section for the Giles Creek Formation is located at Ross River Gorge. It is here proposed that a reference section for the Giles Creek be established at Ulta Bank Creek (Section B). Although access to the Ross River site is excellent, the rock types, bedding character, intraformational facies relationships, and depositional environments of the Giles Creek are unlike those at any other location in the basin. The Giles Creek at Ross River is even anomalous for the N'Dhala thrust sheet. Consideration should be given to moving the type section to Ulta Bank Creek.

Age

The assemblage of hyolithids, brachiopods, gastropods, trilobites, and echinoderms at Ross River Gorge suggests that the formation is early Middle Cambrian in age (Wells et al., 1967). Chancelloria sp. (Middle to Upper Cambrian) were also identified in limestones from the base of the Giles Creek at Ross River (Barry Webby, oral communication), and in the Giles Creek at Wallaby No. 1 well (Laurie, 1982). Wells et al. (1967) believed that the Giles Creek is equivalent to the lower part of the Jay Creek Limestone in the western MacDonnell Ranges and the Waterhouse Range, and to the Tempe Member in the western part of the Amadeus Basin. Stratigraphic relations established by this study show that the Tempe Member may correlate with the Chandler Formation (Figure 5). The Jay Creek Limestone is not recognized as a separate formation by the author because it is readily divisible into the Giles Creek and Shannon formations in the field.

Distribution

In the area of study, the Giles Creek crops out from the present northern margin of the basin south to the Pillar Range, and from the nose of Ooraminna anticline east to the north margin of the Simpson Desert (Figure 2). It crops out in the N'Dhala thrust sheet in the Purple Hills and around Ross River, Fergusson, and Gaylad synclines; in the Phillipson thrust sheet around Ooraminna anticline and Phillipson Pound, at Teresa anticline, and in the Deep Well Range; in the Allambi Hills, and south and east of Centenary Dam; in the Camel Flat thrust sheet in the Train Hills, the Larrier Hills, and the western Rodinga Ranges; and in the Rodinga Ranges thrust sheet in the Pillar and eastern Rodinga Ranges.

Basal Contact

The Giles Creek lies disconformably above the upper Chandler throughout the area. The contact is placed at the base of the recessive and locally fossiliferous interval which lies beneath the interbedded carbonates and mudrocks of the upper units of the Giles Creek. This interval is present at all sections in the Phillipson thrust sheet, and present but thin at sections in the Rodinga Ranges and Camel Flat thrust sheets. It is present at all sections in the N'Dhala thrust sheet except Ross River Gorge. It is composed of yellowish gray and light olive gray dolomitic siltstone and silty dolostone, with lenses of reddish brown coarse siltstone and fine sandstone, and medium light gray, fossiliferous, locally sandy limestone (see FIELD DESCRIPTION OF THE GILES CREEK AND UPPER CHANDLER FORMATIONS, Giles Creek Formation, Phillipson Facies, Unit 1).

In the Phillipson Pound area, the top of the upper Chandler is marked by an olive gray birdseye-rich lime mudstone. In other areas it is marked by a yellowish brown, very thick-bedded, rough-weathering, oncolite-rich dolostone or limestone.

Marker Horizons

Nine distinct marker horizons are recognizable in the Giles Creek and upper Chandler. Markers A and B are found in the Chandler formation, and are laterally extensive throughout Phillipson Pound. Markers C through I are present in the Phillipson Facies of the Giles Creek. Markers C, D, F, and I are gradually obscured by facies change to the north and south, but markers E, G, and H are present at all sections of this facies. The lateral persistence of most markers suggests that similar conditions of carbonate deposition were widespread. Because the markers serve as approximate time horizons, they are useful in comparing relative rates of accumulation.

Marker A lies at the top of the lower Chandler formation. It is a laterally extensive white nodular chert, 0.1 meter to 1 meter thick, composed of quartz (mega- and micro-crystalline), calcite, dolomite, limonite, and hematite, with little relict carbonate texture or structure (Sample 62). Large relict algal domes are locally discernable in outcrop. The marker is distinguished from other bedded chert in the Chandler Formation by its greater thickness, white color, and lateral continuity.

Marker B lies in the upper Chandler above marker A. It is a yellowish gray to yellowish brown (fresh), olive brown weathering, thick, massive, cliff-forming, rough-weathering, oncolite-rich, locally vuggy and cherty, cryptalgalaminated dolomitic limestone, limestone, or dolostone (Plate 1). Sample 63 was taken from this horizon.

Marker C lies near the base of the second unit of the Giles Creek. It is a very pale orange (fresh), light orange to light brown weathering, medium- to thick-bedded, cryptalgalaminated limestone, with small, isolated, circular to ovoid, thin, plate-like, smooth masses of brown chert. This marker is distinguished from other chert markers by the color, texture, and morphology of the chert, and by the discontinuity of chert replacement.

<u>Marker D</u> also lies in Unit 2, midway between Markers C and E. It consists of two beds of light gray to grayish orange (fresh) very light gray weathering, cryptalgalaminated, medium- to thick-bedded limestone or dolomitic limestone, with small, medium, large, and very large domal stromatolites which are locally replaced by chert. The beds are often separated by a thin mudrock interval. The weathering color and the abundance of domal stromatolites are distinctive of this marker.

<u>Marker E</u> lies near the top of Unit 2. It consists of two beds of light gray to grayish orange (fresh), grayish orange weathering, thick- to very-thick-bedded, cryptalgalaminated, locally vuggy limestone or dolostone, with small, medium, large, and very large domal stromatolites, cracked algal laminae, algal intraclasts, and planar bands of nearly continuous reddish brown chert, 5 cm to 20 cm thick, which replace cryptalgalaminae (Plate 2). The beds are often separated by a thin mudrock interval.

<u>Marker F</u> lies near the top of Unit 4. It is yellowish gray to grayish orange (fresh), dark yellowish orange weathering, cryptalgalaminated, very thick-bedded, locally vuggy, stylolitic limestone or dolomitic limestone, with small chert nodules, algal intraclasts, small, medium, and large domal stromatolities, and a horizon of cryptalgalaminae which have been replaced by isolated lenses of reddish brown chert 10 cm to 20 cm high and 20 cm to 50 cm wide.

<u>Marker G</u> lies at the top of Unit 4, above Marker F, at a sharp break in slope. It is a pale grayish orange (fresh), light olive gray weathering, thick- to very thick-bedded, cryptalgalaminated limestone

or dolostone, with small, medium, and large domal stromatolites, mud cracks, and black nodular chert which locally replaces domal stromatolites. This horizon is distinguished from others by its position at a sharp break in slope and its abundance of black nodular chert. The dark color of the chert may be due to the inclusion of organic matter.

Marker H lies at the top of Unit 5. It is a light brownish gray (fresh), light bluish gray weathering, medium- to thick-bedded dolostone, which is smooth, rounded, and massive at the base, and cryptalgalaminated at the top. It is underlain by a thin horizon of mudrock, which is underlain by a carbonate bed which contains small nodules of moderate red chert. Sample 25 was taken from the base of Marker H.

Marker I lies near the base of Unit 6. It is a grayish orange pink (fresh), light brown weathering, thick- to very thick-bedded, locally oolitic dolostone or calcitic dolostone, which is generally massive at the base, but contains cryptalgalaminae and small to medium domal stromatolites near the top. The basal bedding surface of this marker is invariably covered with small, circular to ovoid pits, 1 mm to 3 mm in diameter, which impart a vesicular-like texture to the rock. This feature is unique to this marker.

FIELD DESCRIPTION OF THE GILES CREEK AND UPPER CHANDLER FORMATIONS

General Statement

Six facies of the Giles Creek are recognized in the study area. In this report, the term "facies" refers to a mappable and areally restricted part of a defined stratigraphic body which is composed of one or more characteristic lithofacies. The Phillipson Facies crops out in the Allambi Hills and eastern Train Hills, around Phillipson Pound, and around Ooraminna and Teresa anticlines. Outcrops of the North Phillipson Facies are present along the north flank of Missionary syncline; outcrops of the northern facies are located around Ross River, Fergusson, and Gaylad synclines; outcrops of the Southern Facies are present along the southern flank of Camel Flat syncline and in the Pillar Range; and outcrops of the Eastern Facies are present in the Centenary Hills (Figure 8). Outcrops which lie in a zone of transition separating the Phillipson Facies from the Southern Facies are collectively assigned to the Transitional Facies. Field descriptions of the Northern and Phillipson Facies were extremely detailed. Considerably less information was obtained on the Southern, Eastern, North Phillipson, and Transitional Facies.

The upper Chandler shows little facies change throughout the area.

Upper Chandler Formation

Massive boundstone and wackestone are characteristic of the upper Chandler. These beds are overlain and underlain by thinner bedded boundstone and lime mudstone in some areas. The carbonates range in composition from limestone and dolomitic limestone to dolostone and calcitic dolostone, and are interbedded with siltstone, mudstone, and mudshale.

The massive carbonates are pale yellowish brown in color (fresh), and the others are commonly grayish orange, light gray, or grayish orange pink. Very pale orange, yellowish gray, pale red, light brown, and olive gray carbonates are present locally. Light olive gray, grayish orange, pale yellowish orange, grayish red, and white are colors (fresh) common in the mudrocks. Grayish yellow, light brown, and moderate brown mudrocks are present but rare.

Carbonates above the massive beds are commonly very thick bedded, but are thin, medium, and thick bedded locally. Carbonates below the massive beds are frequently very thick bedded. Medium and thick bedding is present but rare. Very thin bedding is most common in the mudrocks.

Birdseye-rich lime mudstone (Plate 3), oncolite wackestone, and cryptalgalaminated, oncolite-bearing boundstone are the carbonate rock types common in the upper Chandler. The massive carbonates are invariably oncolitic and commonly cryptalgalaminated (Plate 1). Differential weathering of the oncolites imparts a pitted texture to the surface of these rocks. Cryptalgalaminae are rarely discernible in outcrop. Algal intraclasts are present in some beds of boundstone and wackestone. One horizon of fossiliferous dolomite mudstone was found at the North Phillipson section. Wells (oral communication, 1980) tentatively regarded the fossils as hyolithids. Borings (Plate 4) were found in a bed of lime mudstone at the Surprise anticline section.

Domal stromatolites are not abundant in the upper Chandler. Small and medium domes are most common, large and very large domes are rare.

Very large domes were found only above the massive oncolitic beds. Wavy parallel and planar cryptalgalaminae are abundant in beds of boundstone. Some are cracked and fragmented, possibly due to desiccation. Thrombolites were recognized in this unit in the Larrier Hills, Train Hills, and at North Ross River by Oaks (oral communication, 1982).

A moderate amount of chert is present in the upper Chandler. Although the amount is less than that in the lower Chandler, it is nevertheless significant. Replacement commonly takes place in the form of small lenses, less frequently in the form of nodules, and locally in the form of plates. In some beds the chert preferentially replaces cryptalgalaminae or domal stromatolites.

Carbonates in the upper Chandler are generally resistant to erosion; terrigenous-rich carbonates and mudrocks are recessive. The massive carbonates form prominent strike ridges.

Manganese dendrites are common in the carbonates. Pseudomorphs of chert after gypsum(?) are present but very rare. Fetid and glauconitic carbonates are present in some areas.

Contacts with adjoining units are discussed under "Stratigraphy." In the area studied, the thickness of the upper Chandler ranges from five meters at Ross River Gorge to 61 meters at the Teresa anticline section (Figure 13).

Features unique to the upper Chandler are oncolitic carbonates and birdseye-rich lime mudstone.

Giles Creek Formation

Northern Facies

Outcrops of the Northern Facies of the Giles Creek were observed on the south flank of Fergusson and Gaylad syncline, and on the south, north, and northwest flanks of Ross River syncline. Remarkable similarities exist between outcrops of the Giles Creek at all locations except Ross River Gorge.

The top of the Giles Creek is tectonically absent at the Ringwood section, so that accurate comparison of this section with other sections of the Northern Facies cannot be made.

Outcrops of the Giles Creek on the south flank of Ross River and Fergusson synclines are very similar. In these areas the formation can be divided into three distinct units.

The lowermost unit, Unit A, consists of fine-crystalline, medium gray, weakly fetid dolomite mudstone and oncolitic dolomite wackestone and packstone, interbedded with white and yellowish gray recessive siltstone or silty dolostone. Bedding in the carbonates is thick to very thick. Very small isolated nodules of chert are present in carbonates at the top of the unit.

Unit B is composed of fine-crystalline, locally silty, algal intraclast-bearing, cryptalgalaminated dolomite and lime boundstone, and minor dolomite and lime mudstone, interbedded with recessive and covered siltstone, mudstone, and silty carbonates. Limestones are slightly more abundant than dolostones. Laminae which alternate in composition from limestone to dolostone are common in the boundstone. Medium, large, and very large domal stromat-olites are present but rare. Bedding in most carbonates is very thick. Very small isolated nodules of chert are common in the carbonates. Most carbonates are light gray, very pale orange, grayish yellow, light olive gray, or yellowish gray (fresh), and most mudrocks are white to pale greenish yellow. The carbonate mudstone is cross-stratified locally (Plate 5).

Unit C is composed of locally silty and oolitic, fine- to very fine-crystalline, algal-intraclast-rich, cryptalgalaminated lime or dolomite boundstone, and lime or dolomite mudstone, interbedded with recessive mudrocks and silty carbonates. Limestone and dolostone are present in approximately equal amounts. Laminae which alternate in composition from limestone to dolostone are common. Small, medium, and large domal stromatolites are present but rare. Cryptalgalaminae are frequently cracked and fragmented. Hopper-shaped halite molds were found in a dolomite mudstone near the top of this unit (Plate 6). Bedding in the carbonates is usually medium or thick, but occasionally thin or very thick. Silica replaces entire horizons of thin-bedded carbonates near the top of the unit. Grayish yellow, very pale orange, and yellowish brown (fresh) carbonates, and moderate brown, grayish pink, and white mudrocks are present in Unit C.

On the northwest flank of Ross River syncline, the Giles Creek is composed of a basal recessive unit, an overlying thick, cliff-forming dolostone, and interbedded carbonates and mudrocks at the top. Wells et al. (1967) reported Biconulites and Girvanella at the base. The overlying dolostone is fine to medium crystalline, thin to medium bedded and rich in oncolites. Domal stromatolites and birdseye structure are present in some horizons. Interbedded cryptalgalaminated boundstone and variegated mudrocks and silty carbonates lie at the top. Limestone becomes more abundant near the top.

On the south flank of the Gaylad syncline, the Giles Creek is composed of medium crystalline, oncolitic, locally oolitic and fossiliferous, grayish orange (fresh) dolostone. Birdseye structure is present in most horizons. The unit forms strike ridges. Wells et al. (1967) identified the fossils from this area as trilobites.

Pronounced differences in the depositional texture, sedimentary structure, bedding style, color, and types of grains in the carbonates of the Giles Creek at Ross River Gorge suggest rapid facies change to the north. J.W. Keith (1974, p. 28-30) described the Giles Creek at Ross River Gorge as follows:

> The top 326 feet of the upper Giles Creek consists of thinly interbedded dolomitized carbonates of the following types:
>
> 1. 0.5 to 2.0 ft. beds of irregularly laminated dolomudstone and fine mud clast grainstone ...
>
> 2. Beds up to several feet thick of layered domal laminated stromatolites.
>
> 3. Dolomudstone beds about 0.5 feet thick crowded with small (1-2 mm) fenestral voids, all sparry dolomite filled.
>
> 4. Massive churned dolomudstone beds up to 5 feet thick.
>
> 5. Dolmud clast grainstones to packstones up to several inches thick overlying scoured disconformities.
>
> Underlying the above is 101 feet of dolomitized carbonate deposited in a slightly deeper, shelf lagoon with somewhat better water circulation. The top 41 feet consists of thinly (½ to 5 ft.) interbedded massive dolomudstone with cemented fenestral voids, cemented dolmud clast and oolite grainstones ... The lower 60 feet consists of very thinly (¼ to 1 ft.) interbedded dolmudstone and dolmud clast grainstone and low angle crossbedded mud clast grainstone. Bituminous partings are frequent. There are a few thin beds of cemented oolite

and oncolite grainstone.

The Lower Giles Creek [478 feet] consists of various combinations of:

a) Mostly dark to dusky yellowish brown moderately bituminous and quartz silty limewackestones and less argillaceous, bituminous and very calcareous quartz siltstone. Both contain about 20% skeletal debris including trilobite and brachiopod fragments and Hyolithes.

b) About equal dusky yellowish brown very bituminous and argillaceous limemudstone and greenish gray claymudstone.

Grainstones, mud clasts, churned dolomudstones, and scoured disconformities were not found in other outcrops of the Northern Facies. Ross River Gorge is also the only location where a thick, dark, strongly fetid, richly fossiliferous limestone with siltstone interbeds is found in the Giles Creek.

North Phillipson Facies

The North Phillipson Facies was observed on the north flank of Missionary syncline. There the base of the Giles Creek is composed of cryptalgalaminated boundstone, algal intraclast wackestone, carbonate mudstone, and variegated mudrocks. Medium domal stromatolites are common in the boundstone. Some carbonates are fetid, and most contain small amounts of chert. Halite molds are present in the carbonate mudstone locally.

Above the base, the boundstone contains small, medium, and large domal stromatolites, and the carbonate mudstone is symmetrically and asymmetrically rippled, tabular and trough cross-stratified, and locally sandy (Plate 7). Algal intraclasts, oolites, and birdseye structure are present in some carbonates. Chert is present in the form of small nodules, plates, and lenses.

The top of the unit is composed of cryptalgalaminated boundstone; mudcracked, birdseye-rich, locally sandy carbonate mudstone; oolite grainstone; and mudrocks. Small and medium domal stromatolites are common in the boundstone. Chert is present in small amounts.

Phillipson Facies

General Statement

The Phillipson Facies of the Giles Creek can be divided into six lithologically distinct units. Subdivision of the Giles Creek enhances its mappability and segregates genetically distinct parts of the formation.

Unit 1

The lowermost unit of the Giles Creek is composed of dolomitic and calcitic siltstone and mudstone, with local thin lenses of sandy and silty fossiliferous wackestone and packstone. Trilobites, hyolithids, echinoderms, and calcareous algae (?) (possibly Epiphyton) have been identified in the carbonates (Plates 8 and 9). Silty dolostone, silty dolomitic limestone, and dolomitic sandstone are present in small amounts. Carbonates comprise less than 5% of the thickness of the unit in outcrop.

The carbonates are commonly medium light gray, yellowish gray, or light olive gray (fresh), and the mudrocks are yellowish gray to very pale orange. Sandstones and very coarse siltstones are frequently pale reddish brown, primarily because they contain finely disseminated hematite.

The fossiliferous horizons are rich in pellets and locally burrowed. Small chert nodules are present but rare. Algal structures are lacking. In some beds the carbonate grains and matrix have recrystallized to coarse and very coarse spar.

Carbonate intraclasts are present in some mudrocks. No sedimentary structures were found in the mudrocks.

Thin sandstones are present in Unit 1 in the eastern Train Hills. The sandstones are fine grained, well sorted, and display climbing and non-climbing tabular cross-stratification. Twelve meters of sand were intersected in Unit 1 at Dingo No. 1 well.

Unit 1 is recessive, frequently covered, and forms strike valleys. The unit is best exposed where dips are low, or where it is overlain by a thick resistant carbonate.

The base of the unit is placed at the uppermost carbonate of the upper Chandler, and the top is placed at the base of the lowermost resistant carbonate in the interbedded carbonates and mudrocks of Unit 2. The contact with Unit 2 is commonly gradational through 10 meters.

The thickness of Unit 1 ranges from eight meters at the Brumby anticline section to 63 meters at the Phillipson syncline section. It is thickest in the Phillipson Pound area and thins gradually to the south (Figure 15).

Unit 2

Unit 2 is composed of cherty boundstone, packstone, and crystalline carbonate, interbedded with calcitic and dolomitic siltstone, mudstone, and mudshale. Cryptalgalaminated pellet- and algal-intraclast-rich boundstone and algal-intraclast packstone are common. Calcispheres and cracked and fragmented cryptalgalaminae are present in some beds of boundstone. Dolostone, calcitic dolostone, and dolomitic limestone are common; limestone is present but rare. Most carbonates are very thick bedded, some are thick bedded, and a few are medium bedded. A very thick, massive, cliff-forming silty carbonate is present at the base of the unit in some areas. At Surprise anticline, the bed contains scattered grains of quartz sand and tabular and trough cross-stratification. Carbonates in Unit 2 are very fine to very coarse crystalline.

Manganese dendrites are common in the carbonates. Some beds contain small vugs. Some beds are weakly fetid. Birdseye structure is present near the base of the unit at the Cockatoo section. A thin bed of silicified oolites was found in this unit at the West Todd River section.

A variety of orange, pink, and brown colors (fresh) are common in the carbonates. Hues of 5YR and 10YR with chroma of 2 to 6 and values of 4 to 8 are most common. Lesser amounts of medium and light gray carbonates are also present. Nearly all siltstone and mudstone is white (fresh). The shale is highly variegated, though most has hues of 5R (red), N (gray), 5RP (purple), or 5YR (brown).

Wavy parallel and planar cyrptalgalaminae and small and medium domal stromatolites are common in the carbonates (Plate 10). Large domal stromatolites are rare, and very large domal stromatolites are very rare. Columnar stromatolites are present at the Teresa anticline section (Plate 11).

More chert is present in Unit 2 than in any other unit of the Giles Creek. Replacement frequently occurs in the form of small nodules or thin plates. In some beds the chert preferentially replaces cryptalgalaminae or domal stromatolites. Lenses of chert 5 cm high and

60 cm wide were found in carbonates at the base of the unit southwest of the south Allambi section.

Unit 2 forms the stratigraphically lower strike ridge of the Giles Creek. The carbonates form resistant "steps" between recessive mudrocks and terrigenous-rich carbonates. Massive carbonates found locally at the base form moderately steep escarpments.

The lowermost pale red calcitic mudstone or shale above Marker E marks the contact between Units 2 and 3. Unit 3 forms a distinct topographic break between Units 2 and 4.

The thickness of Unit 2 ranges from 14 meters at the Centenary section to 117 meters at the Phillipson syncline section. The unit is thickest in the Phillipson Pound area and thins to the south and southeast (Figure 16).

Unit 3

The third unit of the Giles Creek is composed entirely of pale red to grayish red (fresh) calcitic mudstone or shale. Colors suggestive of oxidation are abundant in the mudrocks of both Units 3 and 4. The unit is invariably recessive, usually covered, and forms strike valleys where thick. Apart from fissility of shale, no sedimentary structures were found in outcrop. The unit is generally very thin, but thickens in the Phillipson Pound area. Thicknesses range from two meters at the Brumby anticline and north Phillipson sections to 16 meters at the south Ooraminna section. The contact with Unit 4 is placed at the base of the lowermost resistant carbonate overlying the red mudrocks of Unit 3.

Unit 4

Unit 4 is composed of interbedded micaceous mudshale and cryptalgalaminated boundstone, with minor amounts of carbonate mudstone, algal intraclast wackestone, and clayshale. Most carbonates in Unit 4 are limestone or dolomitic limestone, although dolostone and calcitic dolostone are present in small amounts. Thick to very thick bedding is common in the carbonates; medium bedding is present but rare. Most carbonates are very fine to fine crystalline.

Yellowish gray, very pale orange, pale yellowish brown, moderate orange pink, and grayish orange pink are colors (fresh) common in the carbonates. Light olive gray carbonates are present but rare. Nearly all mudrocks are grayish red. Mudrocks which are white, very pale orange, moderate olive brown, and grayish orange pink are present in minor amounts.

Wavy parallel and planar cryptalgalaminae, and small and medium domal stromatolites are abundant in Unit 4. Large domes are rare, very large domes are very rare. A few Collenia domes were recognized in carbonates at the south Brumby section.

Chert is common in some beds of carbonate in the fourth unit. Most is present in the form of isolated lenses or nodules; some is present in the form of thin plates. Replacement is restricted to select cryptalgalaminae or domal stromatolites in some horizons.

Manganese dendrites, cracked and fragmented cryptalgalaminae, oolites (Plate 13), and alternating laminae of limestone and dolostone are present in some carbonates. Pseudomorphs of calcite after anhydrite (Plate 12), mudcracks, intraformational breccia, fine-laminoid fenestral fabric, and small vugs are present locally.

The topographic expression of Unit 4 is similar to that of Unit 2. Carbonates are generally resistant to erosion, and mudrocks and terrigenous-rich carbonates are recessive and usually covered. The unit forms the base of the stratigraphically higher strike ridge in the Giles Creek.

The contact with Unit 5 is placed at the top of Marker G. It lies at a break in slope beneath a series of mudrocks and increasingly terrigenous, more recessive carbonates.

The unit ranges in thickness from 26 meters at the south Allambi section to 65 meters at the south Ooraminna section. Unit 4 also thins southward (Figure 18).

Interbeds of pale red mudstone are characteristic of Unit 4.

Unit 5

Unit 5 is composed largely of very fine to very coarse crystalline, locally silty dolostone and dolomitic limestone, with interbeds of micaceous mudstone and mudshale. Limestones and dolomitic limestone are present in small amounts. Lime-mud- and algal intraclast-, pellet-, and oolite-bearing, cryptalgalaminated boundstone and crystalline carbonate are the dominant carbonate rock types in Unit 5. Pellet and algal intraclast wackestone, and pellet and lime-mud-intraclast grainstone are present in lesser amounts. A thin horizon of dolocalcrete was found at the Surprise anticline section (Plate 14). Carbonates are commonly very thick bedded, less commonly thick bedded, rarely medium bedded, and very rarely thin bedded.

Light gray, white, and grayish orange (fresh) carbonates are common in Unit 5. Grayish orange pink, very pale orange, and pale red carbonates are less common; pale yellowish brown, light brownish gray, grayish red, light brown, light olive gray, and yellowish gray carbonates are present but rare. Mudrocks in Unit 5 are highly variegated. Most are white, grayish yellow, or very pale orange (fresh). Others have hues of 5YR (brown), 10YR (yellow), 5R (red), 5RP (purple), N (gray), or 5B (blue).

Domal stromatolites are abundant in Unit 5. Small and medium domes are common, large and very large domes are relatively rare. Despite the small number of very large domal stromatolites, more are present in this unit than in any other. Medium Collenia domes were found in a few outcrops of Unit 5. Most carbonates contain wavy parallel or planar cryptalgalaminae. Chert is present in small amounts, commonly in the form of nodules. Selective replacement of algal structures was not observed in Unit 5.

Manganese dendrites, alternating laminae of limestone and dolostone, and cracked and fragmented cryptalgalaminae are common in many carbonates (Plate 15). Some carbonates contain small cylindrical vugs, mudcracks, and intraformational breccia.

In the Phillipson Pound area, the fifth unit forms either the upper part of the stratigraphically higher strike ridge or, less commonly, a third strike ridge. It is separated from Unit 4 by a sharp break in slope. In areas south of Phillipson Pound, the unit forms small hills topographically lower than Unit 4, or a series of low dip slopes beyond the ridge crest at the top of Unit 4.

The contact with Unit 6 is placed at the top of Marker H.

Unit 5 thins rapidly from the Phillipson Pound area southward. The thickness of Unit 5 ranges from 98 meters at the Phillipson syncline section to 13 meters at the south Allambi section.

Mudcracks, a paucity of chert, variegated mudrocks, and very large domal stromatolites are characteristic of Unit 5.

Unit 6

The uppermost unit of the Giles Creek is composed of interbedded siltstone, mudshale, and silty calcitic dolostone and dolostone. Minor amounts of silty dolomitic limestone and limestone are also present. Boundstone and lime mudstone are the dominant rock types in this unit. An upward decrease in the thickness of carbonate beds takes place in Unit 6. Bedding thickness ranges from very thick to thin.

Most carbonates in Unit 6 are light gray or grayish orange pink (fresh), some are light brownish gray or pale yellowish brown, and a few are pale red or pink, very pale orange, brownish gray, or light olive gray. Light gray, reddish brown, pale red purple, pale olive, and yellowish gray mudrocks are common in this unit. Light brown mudrocks are present in minor amounts.

Small domal stromatolites and wavy parallel and planar cryptalgalaminae are common in the carbonates of Unit 6. Medium, large, and very large domes are present but rare (Plate 16).

Alternating laminae of limestone and dolostone are common in the carbonates. Intraformational breccia, oolites, cracked and fragmented cryptalgalaminae, and manganese dendrites are present locally. Fetid beds are present but rare. Halite molds (Plate 4) were found in this unit at the Phillipson syncline section.

Very little chert is present in Unit 6. Where present, it takes the shape of small plates, lenses, or nodules.

Unit 6 is characteristically recessive. It forms gentle slopes or shows little topographic relief. The upper parts of the unit crop out in low alluvial areas between the more resistant units of the Giles Creek and Shannon.

The contact with the Shannon Formation is discussed under STRATIGRAPHY.

The thickness of Unit 6 ranges from 101 meters at the Yam Creek anticline section to 15 meters at the south Allambi section. Unit 6 also thins to the south (Figure 20).

Eastern Facies

The Eastern Facies of the Giles Creek is lithologically similar to the Phillipson Facies. The Eastern Facies, however, is much thicker and contains no Phillipson Facies marker horizons. It is limited in its known extent to a small part of a window in the Hi Jinx folded thrust complex, northeast of Centenary Dam. In this area, the Giles Creek consists of a recessive unit at the base, an overlying thick dolostone, and interbedded dolostone and mudrocks at the top.

Where exposed, the basal unit is composed of yellowish gray dolomitic siltstone and silty dolostone. Above this is a medium crystalline, thick- to very thick-bedded, rough-weathering, thick, grayish orange dolostone. Medium domal stromatolites are present near the top of the dolostone. The uppermost unit is composed of interbedded grayish green and pale red dolomitic siltstone and locally oolitic, cryptalgalaminated light gray dolomite boundstone. Small, medium, and large domal stromatolites are present in some beds of the boundstone. Limestone is present but rare. Large nodular chert is present in carbonates near the top of the unit.

Southern Facies

The Southern Facies of the Giles Creek is well exposed in the Rodinga and Pillar Ranges. An increase in the amount of oolitic carbonates and the loss of Phillipson Facies marker horizons suggest southward facies change across Camel Flat syncline.

Along the south flank of Camel Flat syncline, the Giles Creek consists of a thick recessive interval at the base and interbedded mudrocks, carbonates, and silty carbonates at the top. Locally, cherty cryptalgalaminated boundstone is present near the base. Many contain small and medium domal stromatolites. The boundstone becomes increasingly oolitic upsection, and locally grades into oolitic grainstone at the top. The ratio of calcite to dolomite in the carbonates is highly variable and shows no consistent relation to stratigraphic position. Bedding in the carbonates is medium to very thick. Thick to very thick bedding is most common.

Large nodular chert is present in carbonates at the top of the east Desert Bore section. Symmetrical ripples in oolite grainstone and birdseye structure in lime mudstone were found in the Giles Creek in the Pillar Range.

Transitional Facies

A zone of transition lies between the Phillipson Facies and the Southern Facies of the Giles Creek. The marker horizons of the Phillipson Facies and the oolitic carbonates of the Southern Facies are both missing in this area.

At the Bluebush section, the Giles Creek is composed of a recessive dolomitic mudstone at the base and interbedded carbonates and mudrocks at the top. Most of the carbonates are cryptalgalaminated dolomite or lime boundstone, with small, medium and large domal stromatolites. At the west Steele Gap section, a thick oncolitic mudstone overlies the basal recessive unit.

The topographic expression of the Giles Creek becomes increasingly subdued southward. The two ridges characteristic of the Phillipson Facies are present only in the west Allambi Hills.

MUDROCKS

General Statement

Many of the recessive beds in the Giles Creek and upper Chandler are composed of calcitic or dolomitic siltstone, mudstone, clayshale, or mudshale. The mudrocks grade laterally and vertically into silty limestone and silty dolostone. Together the mudrocks and terrigenous-rich carbonates comprise over half of the volume of Giles Creek at most locations. Good exposures of the mudrocks are rare. They are best exposed in stream cuts and at low dips beneath protective carbonate caps. Aside from fissility, no sedimentary structures were observed in outcrop.

Composition and Abundance

The mudrocks are composed of quartz, K-feldspar (including microcline), anorthoclase, illite (including muscovite and biotite), kaolinite, smectite, plagioclase, and hematite, with trace amounts of vermiculite, chlorite, and zircon. Dolomite is the common cementing agent in Units 1, 2, 5, and 6. Most of the mudrocks in Units 3 and 4 are cemented with calcite, although some contain minor amounts of dolomite. Silica-cemented mudrocks are found in minor amounts along the north flank of Camel Flat syncline in Unit 1.

The mudrocks show little variation in composition with stratigraphic position. Each of the major constituents were found in each unit, except hematite, which is abundant only in Unit 4. Grain size is unrelated to composition, and composition is apparently unrelated to fissility.

The influx of terrigenous material oscillated with time during deposition of the Giles Creek. The influx was greatest in Units 1 and 3, decreased sharply in Unit 4, and increased through Units 5 and 6 (Figure 6). The pattern may reflect short periods of marine regression during deposition of Units 1 and 3, and a longer, slower period of regression beginning with the deposition of Unit 4 and culminating during deposition of the basal shale unit of the Shannon.

Provenance and Origin

The amount of terrigenous material in the Giles Creek increases to the west and southwest (Figure 7). Thin sandstones in the Giles Creek in the Train Hills and Allambi Hills, and a thick sandstone in Unit 1 at Dingo No. 1 well indicate that terrigenous grain size also increased in that direction. This suggests that the terrigenous material was shed from a source to the west-southwest, possibly after uplift of that area during the Petermann Ranges orogeny.

Contours of the percent recessive beds define east-west trending areas of high terrigenous influx at the west end of Camel Flat syncline, and north and south of Ooraminna anticline (Figure 7). These may be the eastward extents of paleodistributaries.

Provenance and origin of individual components of the mudrocks are discussed below:

Quartz. Good sorting, a high degree of rounding, and undulosity in some grains suggest that the quartz is detrital. The low percentage of undulose and polycrystalline quartz suggests that the quartz was derived ultimately from a plutonic or middle to upper rank metamorphic source (Basu et al., 1975). The association of quartz with K-feldspar, plagioclase, and mica, and the absence of olivine and pyroxene indicate that the source may have been acidic in composition. The absence of olivine and pyroxene may be due to extensive weathering or prolonged transport. The quartz was probably shed from the Musgrave-Mann Complex or the Olia Gneiss (Figure 1).

Much of the silica in the mudrocks is present in the form of chert. In most cases, chert is a replacement feature or a pore fill, and formed either syngenetically or epigenetically. The occurrence of well rounded and well sorted grains of chert indicates that some is also detrital. The detrital chert was probably derived from Proterozoic sediments in the southwest, perhaps the Inindia or Winnall Beds, or the Bitter Springs Formation.

Syntaxial quartz overgrowths present in Sample 209 are clearly authigenic.

Feldspars. Good sorting and a high degree of rounding suggest that the feldspars are detrital. The abundance of potassium feldspar, the presence of twinned plagioclase (albite), and the association of feldspars with quartz and micas suggest that they were derived from an acidic igneous or metamorphic source. Like quartz, the feldspars were probably derived from the Musgrave-Mann Complex or the Olia Gneiss (Figure 1).

Illite. The presence of 200 m.y. old illite in modern sediments of the Mississippi River delta, and 300 m.y. old illite in modern sediments of the Rappahannock River suggests that most illite is detrital (Grim, 1968). Most illite in the mudrocks of the Giles Creek and the upper Chandler may also be detrital. Minor amounts may have formed in the marine environment from smectite, following adsorption of K and Mg, respectively, and collapse of the smectite structure (Grim, 1968). Illite forms in alkaline environments by weathering of acidic igneous or metamorphic rocks rich in K and Al. Illite in the mudrocks of the Giles Creek and upper Chandler may have been a weathering product of micas and feldspars in the Musgrave-Mann Complex or the Olia Gneiss, and formed in an environment in which rainfall and leaching were moderate and intermittent.

Although it is nearly ubiquitious throughout the world's oceans, the greatest concentrations of illite are present above 10° north latitude and below 45° south latitude (Rateev et al., 1969). Illite is least abundant offshore from rivers draining hot and humid continental areas.

Smectite. The formation of smectite is favored by high concentrations of Ca, Na, Mg, and Fe, a high Si:Al ratio, and an alkaline environment. Although the marine environment meets these requirements, only minor amounts are apparently formed in seawater (Grim, 1968). This suggests that most smectite is detrital in origin, and probably formed by weathering of basic igneous rocks in areas where leaching is negligible. The smectite in mudrocks of the Giles Creek and upper Chandler was probably derived from Precambrian mafics and ultamafics in the southwest. Smectite can also form from acidic igneous rocks in the initial stages of weathering, but only if leaching is minimal and adequate amounts of magnesium are present (Grim, 1968).

Kaolinite. Grim (1968, pp. 536-537) indicated that calcareous sediments are likely to have little or no kaolinite. The presence of calcium in the marine environment inhibits the formation of authigenic kaolinite, and detrital kaolinite alters to illite or chlorite in the marine environment. This suggests that kaolinite in the Giles Creek and upper Chandler is either forming at the present surface by weathering of detrital grains, or is detrital and was deposited in the marine environment faster than it could be altered. The presence of kaolinite in cuttings of the Giles Creek at Dingo No. 1 Well suggests that at least some is detrital. The detrital kaolinite was probably derived from the Precambrian basement in the southwest. Because the formation of kaolinite is favored by low concentrations of Na, K, Ca, and Mg, acidic weathering regimes, and a low Si:Al ratio, kaolinite in the mudrocks of the Giles Creek and upper Chandler probably formed in an environment with high rainfall and leaching. Similar paleoenvironmental implications are suggested by the abundance of kaolinite in modern equatorial marine environments (Rateev et al., 1969).

Hematite. Concentrations of hematite around biotite grains in mudrock cuttings from Dingo No. 1 Well suggest that most of the hematite formed as a syngenetic alteration product of biotite. Walker (1967) found that syngenetic hematite forms from biotite under arid to humid, hot conditions.

Some hematite may have formed by oxidation of pyrite at the present surface, and some may be detrital.

Carbonates. Calcite formed either as an authigenic precipitate from seawater or by inversion of aragonite or high-Mg calcite. Dolomite formed by secondary replacement of calcite (see SEQUENCE OF DIAGENETIC EVENTS, Carbonates, Dolomitization).

Vermiculite. Trace amounts of vermiculite were detected in the mudrocks. The vermiculite is probably detrital, and may have formed by the weathering of biotite in basement rocks to the southwest.

Chlorite. Chlorite may be either authigenic or detrital. Where detrital, its presence suggests aridity. It may have formed in the marine environment as a diagenetic product of kaolinite (Grim, 1968, p. 537), or it may have been transported to the sea following degradation of ferromagnesian minerals in basement rocks to the southwest.

Zircon. The presence of rounded zircon suggests that it is detrital. It was probably derived from basement rocks or Proterozoic sediments in the southwest.

Color

Colors common in the mudrocks are red (5R), purple (5RP), brown (5YR), orange (10YR), yellow (5Y), olive (5Y), gray (N) and white (N). The gradation from red to white is probably related to the oxidation state of iron, and probably reflects a decreasing ratio of Fe^{+3} to Fe^{+2} in the sediment. Potter et al. (1980) indicated that grain size and the amount of organic carbon are also factors which control the color of terrigenous sediments.

ACID-INSOLUBLE RESIDUES

Composition and Abundance

Acid-insoluble residues of 38 carbonate samples of the Giles Creek and the upper Chandler were analyzed in the laboratory. Composition and relative abundance of most constituents were determined by X-ray diffraction. Thin sections were used for identification of micas, opaque oxide minerals, and organics. In order of decreasing relative abundance, the major constituents of the insoluble residues are quartz, K-feldspar (including microcline), illite (micas), and smectite. Anhydrite is abundant in cuttings of the Giles Creek at Dingo No. 1 and Wallaby No. 1 wells. Organics, kaolinite, plagioclase, limonite, and hematite are present in minor amounts, also in order of decreasing relative abundance. Trace amounts of vermiculite, chlorite(?), pyrophyllite(?), and witherite(?) were also identified.

The erodability of carbonates in the Giles Creek is directly related to percent insoluble residue. Samples of recessive carbonates contain an average of 32.1% (by weight) non-carbonate material (n = 9). Weight percent insoluble residue for these samples ranges from 7.9 to 46.4, with no mode, and a median of 39.7. Samples of resistant carbonates, however, contain an average of only 5.6% (by weight) insoluble residue (n = 29). Values for these carbonates range from 1.3% to 20.0%, with modes of 3.4%, 3.6%, 4.4%, and 5.9%, and a median of 4.4%.

Resistant limestone and dolostone contain nearly equal amounts of insoluble residue. Limestone averages 6.0% insoluble residue by weight, with a maximum of 20.0%, a minimum of 1.6%, a mode of 3.6%, and a median of 4.7% (n = 10). An average of 5.4% insoluble residue (by weight) is present in the dolostone (n = 19). Values range from 1.3% to 14.4%, with modes of 3.5% and 5.9%, and a median of 4.3%.

Non-uniform sampling and a small sample size prohibit correlation of percent insoluble residue with depositional texture and stratigraphic position. However, fluctuations in the amount of insoluble residue are likely to reflect overall trends the amount of terrigenous influx during deposition of the Giles Creek and upper Chandler (Figure 6).

The composition of insoluble residues appears to be unrelated to the degree of dolomitization. Each of the insoluble-residue constituents are present in both dolostone and limestone, except those which occur in trace amounts. Chlorite(?) was identified in one sample of limestone, and vermiculite, witherite(?), and pyrophyllite(?) were each found in one sample of dolostone.

Depositional texture appears to be unrelated to the composition of insoluble residues. Although kaolinite and plagioclase are found only in packstones, crystalline carbonates, and boundstones, minerals which are most abundant in the insoluble residues are present in all carbonate textures.

The composition of insoluble residues shows little variation with stratigraphic position. Although vermiculite, pyrophyllite(?), chlorite(?), and witherite(?) were each found in only one horizon (each stratigraphically different), they are present in small amounts and are not volumetrically significant.

Organics

Organics comprise an average of 11.1% of the insoluble residue and 0.5% of the whole rock by weight (n = 35). Insoluble-residue values range from 0.2% to 42.8%, with modes of 1.7%, 8.8%, and 9.1%, and a median of 8.8%. Whole-rock values range from 0.1% to 2.1%, with a median of 0.5% and a mode of 0.6%. An accurate correlation of percent organics with stratigraphic position cannot be made because of the small sample size and the random pattern of sampling. For these same reasons, correlation of percent organics with depositional texture can only be made for boundstones and crystalline carbonates. Boundstones contain less than average amounts of organics (n = 8), and crystalline carbonates contain amounts which are greater than average (n = 9). The amount of organic material in the carbonates appears to be independent of carbonate composition. Limestone averages 0.4% organics by weight, with a maximum of 0.6%, a minimum of 0.1%, a mode of 0.6%, and a median of 0.4% (n = 10). Dolostone ranges from 0.1% to 2.1% organics, with an average of 0.6%, modes of 0.4% and 0.5%, and a median of 0.5% (n = 25).

Provenance and Origin

Major Components

By analogy with the mudrocks, it is inferred that quartz, feldspar, and mica are detrital (see MUDROCKS, Provenance and Origin). Smectite, vermiculite, and illite are also detrital, although minor amounts of illite may have formed in the marine environment by alteration of kaolinite and smectite. Kaolinite is present both as a detrital mineral and as an epigenetic weathering product of silicates.

The detrital components were probably shed from a source to the west-southwest, following uplift of that area during the Petermann Ranges orogeny.

Minor Components

Origin and provenance of other components of the insoluble residues are discussed below:

Anhydrite. Anhydrite forms in sedimentary rocks as a direct precipitate from seawater or as a dehydration product of gypsum. Some anhydrite in the Giles Creek may be authigenic, but the anhydrite at Dingo No. 1 and Wallaby No. 1 wells is likely to be a product of dehydration.

Opaque Oxides. Limonite and hematite are common constituents of surface samples of the carbonates. In most samples the oxides are concentrated along crystal boundaries or stylolites, in some samples they are present as discrete particles surrounding recrystallized fossil tests, and in others they are disseminated throughout the rock. The oxides are missing in subsurface samples, however, and organic matter and subhedral crystals of pyrite are common. This suggests that the oxides formed epigenetically as an oxidation product of pyrite, and that the pyrite originally precipitated in locally reducing environments around the organic matter. This postulate is supported by reports of pseudomorphs of limonite after pyrite in carbonates at the base of the Giles Creek at North Ross River (Wells et al., 1967). The change from medium gray carbonates in the subsurface to tan and orange carbonates in outcrop also suggests that the oxides formed epigenetically.

Minor amounts of limonite or hematite may have formed by alteration of biotite. The lack of oxides in subsurface samples of carbonates indicates that the iron oxides are not detrital.

The apparent lack of organics in thin sections of surface samples is inconsistent with their abundance in acid-insoluble residues. The organics in thin section may be masked by the oxides.

Organics. The organic fraction of the insoluble residues is probably composed of the remains of a variety of marine biota, including blue-green algae, trilobites, hyolithids, and echinoderms. Land-derived organic matter was presumably nonexistent until the first appearance of abundant land plants in the Late Silurian.

Pyrophyllite(?) and Witherite(?). The mode of formation of pyrophyllite and witherite suggests that they are detrital in origin. Witherite commonly forms in low-temperature hydrothermal veins in sedimentary rocks, and pyrophyllite is often produced by hydrothermal alteration of feldspars.

Because pyrophyllite is structurally similar to montmorillonite (smectite), its identification remains tentative.

Chlorite(?). The origin and provenance of chlorite(?) in the acid-insoluble residues is probably analogous to its origin and provenance in the mudrocks (see MUDROCKS, Provenance and Origin).

DEPOSITIONAL ENVIRONMENT

General Statement

Deposition of the Giles Creek and upper Chandler formations occurred in a variety of coastal and nearshore-shelf environments. The Giles Creek consists of tidal flat, shoal, shoal-margin lagoon, open shelf, and intracoastal lagoon deposits, and is underlain by tidal flat, shoal, and intracoastal lagoon deposits of the upper Chandler. These deposits constitute distinct lithofacies in the Giles Creek and upper Chandler. The lateral relations of these lithofacies are shown in Figures 9 and 10.

A lithofacies is here defined as "... any particular kind of sedimentary rock or distinguishable rock record formed under common environmental conditions of deposition, considered without regard to age of geologic setting or with reference to designated stratigraphic units, and represented by the sum total of the lithologic characteristics ... of the rock" (Gary et al., 1972, p. 412).

Upper Chandler Formation

Mixed Shoal/Tidal Flat/Intracoastal Lagoon Lithofacies

The upper Chandler is composed of cryptalgalaminated boundstone; massive oncolitic boundstone, wackestone and grainstone; lime mudstone; and variegated siltstone, mudstone, and mudshale. The massive oncolitic beds are interpreted as shoal deposits, the carbonates above and below are interpreted as tidal flat deposits, and the mudrocks are interpreted as intracoastal lagoon deposits.

The massive beds are rich in oncolites and birdseye structure, features which are evidence for deposition in a high-energy, shallow-water environment. Although oncolites may be deposited in quiet inter-tidal to subtidal areas, they are formed by agitation in high-energy environments (Wilson, 1975). The abundance of oncolites in these beds suggests that they were deposited in close proximity to the environment in which they formed. The abundance of oncolites and their association with birdseye structure suggests that these sediments were deposited in a relatively shallow shoaling environment.

Deposition of overlying and underlying carbonates on an adjacent tidal flat is suggested by the presence of cryptalgalaminated boundstone with domal stromatolites, and by the mud intraclasts, birdseye structure and pseudomorphs after gypsum in the lime mudstone. These features are present on modern carbonate tidal flats at Abu Dhabi, United Arab Emirates (Schneider, 1975), Andros Island, Bahamas (Ginsburg and Hardie, 1975), and Shark Bay, Western Australia (Hagan and Logan, 1975). Although algal mats are common at each of these areas, domal stromatolites have been reported only at Andros Island. Evaporites are lacking at Andros Island because of its humid climate. Mud intraclasts and birdseye structure are present on tidal flats at all three locations.

Biostromes in the upper Chandler are composed of smooth and pustular laminated stratiform sheets and domal stromatolites. The lack of pre-existing irregularities between the domes suggests that doming of the laminae is a result of growth and not perpetuation of initial synoptic relief on the mats. Synoptic relief of the small, medium, large, and very large domes ranges from 2 cm to 5 cm, 2 cm to 7 cm, 10 cm to 35 cm, and 30 cm to 50 cm, respectively. Lateral linkage of the domes (hemispheroids) suggests that the biostromes formed in a protected intertidal environment (Logan et al., 1964), and smooth and pustular mat types suggest that they formed in the low to middle intertidal zone (Logan et al., 1974). Synoptic relief of the very large domes suggests that the tidal range was at least 0.5 meters. Greater synoptic relief of the larger domes also suggests that these domes grew in deeper water than the smaller domes (Logan, 1961). Stratiform sheets were probably confined to the landward extremities of tidal flats where slopes were gentle and smooth (Logan et al., 1974). Thrombolites were recognized in the upper Chandler in the Larrier Hills, Train Hills, and at North Ross River (Oaks, oral communication, 1982). Thrombolites suggest that deposition of some of the carbonate may have extended into the shallow subtidal zone (Aitken, 1967).

Carbonate-mud intraclasts were recognized in a few beds of boundstone. The intraclasts may represent partially indurated sediment disaggregated and redeposited by storm waves.

The lime mudstone in the upper Chandler is interpreted as a high intertidal to supratidal deposit because it contains abundant birdseye structure and locally contains pseudomorphs after anhydrite.

The interbeds of siltstone, mudstone, and mudshale are interpreted as land-derived sediments which accumulated in an intracoastal lagoon landward of the carbonate tidal flat (Figures 11 and 12). Most were probably deposited below low tide level, but were intermittently exposed at exceptionally low tides or as the sediments accumulated to intertidal levels or higher. Colors suggestive of both oxidizing and reducing conditions are present in the mudrocks. Most mudrocks are highly calcitic or dolomitic, suggesting that significant amounts of carbonate were deposited with the terrigenous material. The carbonate was probably deposited as lime mud which may have been derived from the high-intertidal or supratidal areas of the adjacent tidal flat.

A thin horizon of hyolithid packstone was found at the Phillipson syncline section, and clasts of skeletal grainstone were reported by Keith (1974) in the "basal Giles Creek" (upper Chandler) at Ross River Gorge. The fossils were probably indigenous to the subtidal zone, and were probably transported to the tidal flat by storm waves. If the upper Chandler at Ross River Gorge is subtidal, the fossils may be in place.

In the Phillipson Facies, the oncolitic carbonate lies near the base, stromatolitic carbonate lies higher, and birdseye-rich carbonate is at the top. This sequence suggests overall shallowing upward, and may be related to tectonic uplift, eustatic fall in sea level, or a rate of deposition which exceeded the rate of subsidence.

Giles Creek Formation

Shallow Open-Shelf Lithofacies

The base of the Giles Creek at Ross River Gorge is composed of fetid and fossilferous lime mudstone, wackestone, and packstone, with interbeds of gray calcareous shale. Brachiopods (Keith, 1974), enchinoderms, trilobites, and hyolithids are the major skeletal constituents.

The depositional texture and faunal content of the carbonate suggest that it was deposited on a shallow open shelf with normal-marine salinity and unrestricted circulation. Deposition in an environment with normal-marine salinity is inferred from the abundance of echinoderms (Binyon, 1966) and brachiopods (Rudwick, 1970). Trilobites and hyolithids were also abundant in waters of normal-marine salinity, but may have inhabited waters of higher salinity as well. The fossils are less useful as paleobathymetric indicators because each group may have inhabited a wide range of water depths. Trilobites were abundant in shallow water (Dodd and Stanton, 1981), however, and may indicate that the carbonate was also deposited at relatively shallow depths.

Turbulence was probably low to moderate. Although the abundance of carbonate mud and the presence of intact tests of hyolithids and trilobites suggest that turbulence was low, the presence of suspension-feeding brachiopods suggests that turbulence was at least moderate (Dodd and Stanton, 1981).

Although the shelf waters must have been sufficiently oxygenated to support the marine biota, the fetid character of the limestone, pseudomorphs after pyrite (Wells et al., 1967), and grayish-green colors in the shale suggest that the sediments accumulated in a reducing environment. The presence of bottom-dwelling brachiopods and trilobites suggests that reducing conditions developed below the sediment-water interface.

The shale interbeds are also interpreted as shallow open-shelf deposits. The terrigenous sediments may have been carried to the shelf in tidal channels which locally breached the tidal flat.

Shoal Lithofacies

Above the open-shelf deposits at Ross River Gorge lies oolite and oncolite grainstone, birdseye-rich lime mudstone, and low-angle cross-laminated mudclast grainstone. These sediments are interpreted as shoal-face and shoal-crest deposits, and are analogous to recent carbonate shoal deposits west of Andros Island, Bahamas (Shinn et al., 1969; Ginsburg and Hardie, 1975).

Ooids have long been recognized as common constituents of ancient carbonate shoals. Recent counterparts are well developed at many locations in the Bahamas (Ball, 1967; Purdy, 1963). Oncolites are also common in shoal deposits (Wilson, 1975), and have been identified in the intertidal zone seaward of shoals at Shark Bay, Western Australia (Hagan and Logan, 1975). The oolite and oncolite grainstone in the Giles Creek is interpreted as a deposit which accumulated on the seaward face of a shoal, where energy conditions were conducive to the formation of ooids and oncolites, and sufficient to winnow the fine-grained fraction of the sediment.

The beds of mudclast grainstone and birdseye-rich lime mudstone are interpreted as relatively low-energy supratidal, shoal-crest deposits. Birdseye-rich mudstone has been recognized on the crests of recent shoals at Andros Island, Bahamas (Shinn et al., 1969). Ginsburg and Hardie (1975) noted that the crests of these shoals are exposed 95% to 99% of the time. Mudclasts have been reported on shoals at Shark Bay (Woods and Brown, 1975) and Andros Island (Shinn et al., 1969).

The cross-laminated mudclast grainstone may have formed as currents swept shoal crests at times of exceedingly high tide. Some of the cross-laminated grainstone may have been deposited on the intertidal part of the ridge, where currents are more common.

Shoal-Margin Lagoon Lithofacies

Beds of massive dolomite mudstone and mudclast dolomite grainstone overlie the shoal deposits at Ross River Gorge. These deposits are similar to, and probably correlative with, the massive fetid dolomite mudstone and oncolite-rich dolomite wackestone and packstone near the base of the Giles Creek at South Ross River (Figure 9). The sediments of this lithofacies are interpreted as shoal-margin lagoon deposits (Figures 11 and 12).

The thick dolomite mudstone is analogous to recent lagoonal deposits off the Trucial Coast of Arabia (Kinsman, 1966), and may have been deposited in a similar environment. Thick dolomitic muds associated with tidal flat sediments in the Arab/Darab Formation of Arabia were also interpreted as lagoonal deposits (Wood and Wolfe, 1969). The dolomite mudstone contains horizons of mudclast grainstone interpreted as "spillover" deposits which accumulated landward of the shoal. The grainstone is analogous to deposits accumulating on the landward side of shoals at Andros Island, Bahamas (Shinn et al., 1969). There the clasts are formed by desiccation of carbonate mud during subaerial exposure of the shoal, and are deposited by tidal currents and waves in areas of less agitation toward the shore. The fetid character of the dolomite mud at South Ross River is also suggestive of deposition in a quiet-water environment with restricted circulation.

Wilson (1975) indicated that oncolite-rich carbonate muds are characteristic of lagoonal environments. The oncolites probably formed in an adjacent shoal environment, and were deposited in the lagoon by tidal currents and waves. The lack of grain support in the oncolitic beds and the interbeds of thick dolomite mudstone suggest that the oncolites were transported from their place of origin to a lower energy environment.

Intracoastal Lagoon Lithofacies

Calcitic and dolomitic siltstone, mudstone, mudshale, and clayshale are interbedded with the tidal flat carbonates of the Giles Creek and upper Chandler. In Unit 1 of the Phillipson Facies, the mudrocks contain carbonate (mud?) intraclasts (Felton, 1981); disseminated pyrite (Felton, 1981); thin lenses of silty, locally sandy, burrowed, fossiliferous, pellet-bearing lime wackestone and packstone; and thin lenses of rippled fine sandstone and coarse siltstone. At Dingo No. 1 and Wallaby No. 1 wells, the mudrocks contain anhydrite (Gorter, oral communication, 1982). These sediments are interpreted as deposits which accumulated in a lagoonal environment shoreward of the tidal flat and seaward of the continental mainland, which was locally connected to the open sea by shallow tidal channels (Figure 11). This environment is here called an "intracoastal lagoon," and is similar to the "inshore basin" environment of Aitken (1978). Stream distributaries may have carried fine terrigenous clastics to the lagoon, where they were mixed with carbonate mud from the tidal flat. Recent examples of analogous environments are not known to the writer.

Anhydrite in the mudrocks at Dingo No. 1 and Wallaby No. 1 wells indicate that the water was at least locally hypersaline. The beds of fossiliferous and burrowed limestone suggest that local environments of normal-marine salinity were also present.

Conditions in the intracoastal lagoon were probably reducing in deeper water, but oxidizing in shallower water and in those areas which were subaerially exposed. The oxidized colors of many of the mudrocks in outcrop and the abundance of hematite in mudrock samples from Dingo No. 1 suggest that some mudrocks were deposited in areas of the lagoon exposed for long periods of time above the mid-tide level. The white, gray, and green colored, pyrite-bearing mudrocks were probably deposited in those areas of the lagoon which restricted circulation or limited subaerial exposure, primarily below the level of gravitational and of wind-driven tides. Oxidation in the intracoastal lagoon may also be related to the original abundance of organic matter and sulfates in the sediment. Those sediments lacking organic matter would be unable to support reducing anaerobic bacteria and would remain unaltered even where entirely subaqueous.

The lenses of fine sandstone and coarse siltstone and interpreted as intralagoon channel deposits. Climbing cross-stratification (ripple-drift) in the sandstones suggests that these were areas in which the supply of terrigenous sediment exceeded its rate of removal (Blatt et al., 1980).

The origin of the thin fossiliferous wackestone and packstone is not clearly understood. It may be a storm deposit, or a deposit which accumulated near tidal channels where mixing of marine with hypersaline waters created areas more tolerable to open-marine fauna. Mud support, intact fossils, and the lack of current structures suggest that the limestone was not deposited in tidal channels.

Mixed Tidal Flat/Intracoastal Lagoon Lithofacies

Sediments of the Phillipson, North Phillipson, and Eastern facies are interpreted as mixed tidal flat/intracoastal lagoon deposits.

Similar deposits also comprise the upper part of the Northern Facies and the lower part of the Southern Facies. The mudrocks and terrigenous-rich carbonates (recessive beds) of these facies are interpreted as intracoastal lagoon deposits (as discussed above), and the nonrecessive carbonates are interpreted as tidal flat deposits. Carbonate-grain types, depositional textures, and sedimentary structures indicate that the tidal flat deposits accumulated in the lower intertidal to supratidal zone. Domal and stratiform sheet biostromes are characteristic features of this facies.

Stratiform sheet biostromes are interpreted as predominantly intertidal deposits. They are abundant in the intertidal zones of tidal flats at Andros Island, Bahamas; Shark Bay, Western Australia; and Abu Dhabi, United Arab Emirates. Stratiform sheets locally extend into the supratidal zone at Andros Island (Ginsburg and Hardie, 1975), and into both the supratidal and upper subtidal zones at the Nilemah Embayment of Shark Bay (Woods and Brown, 1975). Pseudomorphs of calcite after anhydrite were found in stratiform sheets in the Giles Creek, and may indicate that some sheets extended into the supratidal zone. Stratiform sheets were probably confined to the landward extremities of the tidal flat where slopes were gentle and smooth (Logan et al., 1974).

Domal stromatolites have not been recognized at Shark Bay and Abu Dhabi, but are well preserved in inferred tidal flat environments in the geologic record (Logan et al., 1964). Small, hollow domal stromatolites have been reported in algal mats on tidal flats at Andros Island (Black, 1933) and in Western Australian salinas (Clark and Teichert, 1946). Domal stromatolites which are both space linked (mode

LLH-S) and close linked (mode LLH-C) are present in tidal flat carbonates of the Giles Creek. The LLH arrangement of the domes suggests that they formed in a protected intertidal environment (Logan et al., 1964). Smooth and pustular mat types are abundant in both the stratiform sheets and domes, and suggest that many of the biostromes formed in the low to middle intertidal zone (Logan et al., 1974). Smooth and pustular mat types are confined to these zones at Shark Bay. Fine-laminoid fenestral fabric is associated with the smooth and pustular mats and is also suggestive of deposition in the lower intertidal zone (Logan, 1974).

Columnar stromatolites are present locally, and also reflect deposition in the low to middle intertidal zone. Columns are abundant in this zone at the Hutchison Embayment of Shark Bay (Hagan and Logan, 1975). Because columnar stromatolites are capable of withstanding moderate wave attack (Logan et al., 1974), they were probably most abundant seaward of the areas suitable for growth of domal and stratiform sheet biostromes.

The synoptic relief of domal stromatolites in the Giles Creek is directly related to the diameter of the stromatolite. Synoptic relief of the small domes ranges from 1 cm to 4 cm, that of the medium domes ranges from 1 cm to 10 cm, synoptic relief of the large domes ranges from 4 cm to 40 cm, and that of the very large domes ranges from 12 cm to 60 cm. A tidal range of at least 0.6 meters is inferred from the maximum synoptic relief of the domes. Greater synoptic relief of the larger domes suggests that they grew in somewhat deeper water than the smaller domes (Logan, 1961).

Many beds of boundstone contain cracked and fragmented cryptalgalaminae. These features suggest that the sediments underwent protracted periods of desiccation, possibly in the supratidal zone following emergence of the intertidal deposits, or in the high intertidal zone between spring tides.

The dolomite and lime mudstone interbedded with the boundstone is also interpreted as a tidal flat deposit. Lime muds are associated with algal sediments in recent tidal flat deposits at Andros Island and Abu Dhabi. Birdseye structure (Shinn, 1968), mudcracks, and halite molds are present in some beds of carbonate mudstone, and suggest that the mudstone was deposited in a supratidal environment. Mudcracks and evaporites are common features of recent sediments in supratidal environments at Shark Bay, Andros Island, and Abu Dhabi. Ripple marks and cross-laminae are also present in some beds of carbonate mudstone. These structures were probably formed by tide- or wind-induced currents on the tidal flat, and suggest that the rocks were deposited in the intertidal zone.

Oncolites and ooids were found in a few beds of carbonate. The oncolites and ooids may have formed on small, local shoals within the tidal flat. Locally derived, storm-generated oncolites are reported in the lower supratidal zones of the Nilemah Embayment, Shark Bay (Woods and Brown, 1975), and ooids are forming today on local, low-relief shoals along the shoreline of the Great Salt Lake, Utah.

Mud- and algal intraclasts are present in some beds of carbonate. The algal clasts may have formed by desiccation of algal mats at times of protracted exposure, and were probably redeposited by tidal and wind-induced currents on the tidal flat. The mudclasts are interpreted as locally derived, redeposited fragments of desiccation-cracked lime mud.

Mudclasts derived from desiccated lime mud are abundant in recent intertidal to supratidal sediments at Andros Island (Ginsburg and Hardie, 1975). Some may have been derived from adjacent subtidal areas during storms. Thin horizons of intraformational breccia were also found in the carbonate, and are interpreted as storm deposits. Similar deposits are found in the upper intertidal and supratidal areas of Shark Bay (Hagan and Logan, 1975; Woods and Brown, 1975).

Pellets are present in some of the tidal-flat deposits. Some of the pellets may be fecal. Pellets are reported as abundant constituents of tidal flat deposits at Abu Dhabi (Schneider, 1975).

Calcispheres were identified in tidal flat carbonates at the Ulta Bank Creek section. Calcispheres have not been reported in recent tidal flat deposits, but are grains which form in shallow water with restricted circulation (Wray, 1977).

A thin horizon of dolocalcrete (Plate 14) was identified in Unit 5 at the Surprise anticline section. The presence of dolocalcrete suggests that local areas of the tidal flat underwent prolonged subaerial exposure. The calcrete may have developed on a local topographic high within the tidal flat, and is probably analogous to similar horizons on shoals at Shark Bay (Woods and Brown, 1975). The calcrete is not interpreted as a terrestrial deposit because of the great inferred distance to the mainland.

The paucity of fauna, the abundance of algal mats, pseudomorphs after evaporites in outcrop, and anhydrite and white gypsum in cores of dolostone at Wallaby No. 1 Well indicate that the tidal flat waters were dominantly hypersaline.

Oolitic Lithofacies

Thin beds of oolite-rich boundstone and oolite grainstone are common near the top of the Southern Facies of the Giles Creek (Figure 12). The oolitic beds are interbedded with tidal flat and intracoastal lagoon deposits, and together comprise the oolitic lithofacies of the Giles Creek.

The occurrence of ooids in intertidal boundstone and the association of oolite grainstone with tidal flat and intracoastal lagoon deposits suggests that the ooids have been transported some distance from their source. The abundance of oolitic beds increases southward, suggesting that the ooids were derived from a source which lay in that direction. The oolitic beds are interpreted as "spillover" deposits derived from an oolite shoal to the south. The presence of an oolite shoal suggests that deeper water of normal-marine salinity existed south of the Pillar Range. The absence of outcrops to the south, however, makes the existence and location of such a shoal conjectural.

Extensive shoals of this type have developed along the margin of the Bahama platform east of Andros Island, north of Exuma Sound, and east of Bimini Island, South Cat Cay, and Browns Cay (Blatt et al., 1980; Purdy, 1961). Purdy (1961) indicated that the oolite deposits at Browns Cay extended nearly five kilometers landward of the seaward margin of the shoal. Extensive oolite spillover lobes at Cat Cay are reported to extend more than 1.5 kilometers onto the Great Bahama Bank (Ball, 1967).

Small ripples are present in beds of oolite grainstone in the Pillar Range. The ripples were probably produced by tide-induced currents on the tidal flats. Although cross-laminae would be useful in determining the dominant direction of oolite transport, none were observed in outcrop.

Oolite washovers are associated with pustular algal mats in ephemeral lagoons behind oolite beach ridges along the shores of the Great Salt Lake, Utah (Oaks, oral communication, 1982). There the oolites form by accretion in hyperslaine water as they are rolled in the surf. Although the oolites in the Giles Creek may have formed in this way, their association with marine intertidal carbonates and the lack of other strand-line or subaerial features suggest that they are indeed intertidal deposits.

PALEOGEOGRAPHY

In Cambrian time, the Amadeus Basin was situated near 20°N latitude and was oriented with its present northern margin rotated nearly 90° to the west (Embleton, 1973). In its present orientation, it lay at the western margin of a large marine embayment which extended across western Queensland into the Northern Territory (Kennard, 1981, Figure 16). The carbonates of the Giles Creek and upper Chandler were deposited at the western edge of the sea, and were mixed with terrigenous sediments derived from an eroding craton to the southwest. The inferred Middle Cambrian paleogeography of the study area is shown in Figures 11 and 12.

Lateral lithofacies relationships show that the margin of the open ocean bordered the northern margin of the study area in early Giles Creek time (Figure 9). An extensive tidal flat covered a large part of the study area, and was separated from the open ocean by shoals and shoal-margin lagoons. Shoal-margin lagoons developed landward of the shoals in low areas of the tidal flat. Westward intertonguing with terrigenous sediments of the Hugh River Shale and the westward increase in grain size and amount of terrigenous material in the Giles Creek suggest that the mainland lay to the west-southwest. The mainland was separated from tidal flats to the northeast by a large intracoastal lagoon.

The lack of outcrops south of the Pillar Range makes paleogeographic interpretation in that area considerably more difficult. Although thickness data support approach to the inferred southern basin margin, evidence for an oolite shoal during deposition of the upper Giles Creek suggests relatively deeper water in that direction. If the latter is true, an arm of the ocean must have extended into this area in late Giles Creek time, and perhaps before.

The enormous lateral extent of the tidal-flat deposits and the lack of well-developed channels suggest that the gradient on the tidal flat was low. Minor fluctuations in sea level, rates of subsidence, or rates of deposition would have caused submergence or emergence of large parts of the tidal flat.

HISTORY OF SEDIMENTATION

Upper Chandler sedimentation began with northeastward migration of a low-relief oncolite shoal during slow retreat of the sea. The rate of progradation was probably rapid. A slower rate of progradation, with even a moderate rate of overall subsidence in the basin, would result in shoal deposits that thicken seaward and back-shoal deposits that thicken landward. Successive rock types in the upper Chandler are thin and nearly uniform in thickness throughout the study area. Migration of the shoal was accompanied by seaward progradation of a back-shoal tidal flat and an adjacent landward intracoastal lagoon. As the rate of deposition increased, as the rate of subsidence decreased, or as sea level gradually lowered, carbonates on the tidal flat accumulated in successively shallower water and many of the intracoastal-lagoon deposits oxidized. Continued gradual subsidence with shifts in the position of terrigenous distributaries allowed for simultaneous deposition of terrigenous material over tidal-flat deposits and lateral accretion of the tidal flat over intracoastal-lagoon deposits. This resulted in interbedding of the deposits from both areas (see CYCLICITY IN SEDIMENTS OF THE GILES CREEK: A MODEL).

The onset of Giles Creek deposition occurred after a rapid southwestward advance of the sea. Open-marine conditions prevailed in the northeast, shoals and shoal-margin lagoons formed at the margin of the open sea, and a broad tidal flat and intracoastal lagoon developed in the southwest (Figure 12). A slow period of regression followed, and resulted in seaward progradation of each environment. In the south, shifts in the position of terrigenous distributaries caused migration of the tidal flat and intracoastal lagoon, and interbedding of deposits from both areas (see CYCLICITY IN SEDIMENTS OF THE GILES CREEK: A MODEL). Giles Creek deposition closed with northward progradation of an oolite shoal south of the study area. Fluctuations in the amount of terrigenous material in the Phillipson Facies show that the regression was interrupted by minor advances of the sea during the deposition of Units 2 and 4 (Figure 6). The regression culminated at the end of Giles Creek time during deposition of the basal shale unit of the Shannon.

The relatively greater thickness of the Giles Creek and upper Chandler in the Phillipson Pound and Ross River-Fergusson syncline areas suggests that these areas subsided at a relatively greater rate during the Middle Cambrian. Some of the effect of differential subsidence in the Phillipson Pound area was offset by salt-induced growth of Ooraminna, Windmill-Todd River, and Brumby anticlines.

CYCLICITY IN SEDIMENTS OF THE GILES CREEK: A MODEL

Cyclic deposition of mudrocks and carbonates occurred during much of Giles Creek time. The entire Phillipson, North Phillipson, and Eastern Facies, the upper part of the Northern Facies, and the lower part of the Southern Facies contain deposits of this type. To account for cyclicity in these sediments, the following model is proposed:

As carbonate production on the tidal flat flourishes, carbonate production in areas near distributaries is inhibited by the influx of terrigenous sediment (Figure 11). With stream avulsion in times of flooding, the position of terrigenous influx shifts to lower areas where deposition of carbonates has not kept pace with subsidence. This enables carbonate production in the area near the former position of the distributary to resume, and results in little admixture of terrigenous sediment with the carbonates. With continued subsidence and nearly constant sea level, the tidal flat accretes over the terrigenous sediments deposited near the former position of the distributary (Figure 12). At the same time, the area near the new distributary experiences an increase in terrigenous influx, and carbonate production slows or stops. With continued subsidence and nearly constant sea level, the terrigenous material accumulates on carbonates deposited in the former position of the tidal flat (Figure 12). Repeated shifts in the position of distributaries would cause periodic advance and retreat of the tidal flat and intracoastal lagoon, and result in interbedding of deposits from both areas. Shifts in the position of distributaries by stream avulsion occur today in the Mississippi River delta (Oaks, oral communication, 1982).

The same effect could be achieved by fluctuations in the amount of terrigenous material from a distributary in a constant position. With continued subsidence and constant sea level, tidal flat carbonates would advance toward the mainland over intracoastal lagoon deposits in times when terrigenous influx was low, and the terrigenous deposits would advance seaward over tidal flat carbonates in times when terrigenous influx was high. However, the abrupt contacts of the carbonates with overlying mudrocks and the paucity of terrigenous material in the carbonates suggest that the sediments were not deposited in this way. Carbonates deposited in an environment with a fluctuating influx of terrigenous material should contain greater amounts of clastics, and contacts with overlying mudrocks should not be consistently abrupt.

It is unlikely that cyclicity resulted from glacial-induced fluctuations in sea level. The change of sea level required to produce cyclic deposition of carbonates and mudrocks in the Giles Creek was small, unlike changes which occurred during Pleistocene glacials. Furthermore, there is little evidence for continental glaciers in the Cambrian (Frakes, 1979).

SEQUENCE OF DIAGENETIC EVENTS

Carbonates

Inversion and Recrystallization

By analogy with modern carbonate sediments, it is inferred that the initial mineralogy of the carbonate muds, grains, and cement was aragonite or high-Mg calcite. The muds and cements which were initially aragonite were probably composed of crystals which were needle-like in shape. Blatt et al. (1980) indicated that most modern carbonate mud is composed of crystals of aragonite, approximately three microns in length and one-half micron in diameter, and early cementation by needle-like aragonite was observed by Ball (1967) in the oolite shoals of the Bahamas, and by Logan (1974) in the intertidal region of Shark Bay, Western Australia.

Subsequent inversion of the aragonite and/or high-Mg calcite to low-Mg calcite may have occurred in either a marine or fresh-water environment. Friedman (1964) believed that the inversion takes place as the sediments lose contact with the marine environment during subaerial exposure. Berner (1971), however, was able to show that although fresh water greatly accelerates the process, the transformation can occur in seawater with sufficient time. The work of Berner is supported by field evidence of inversion in the deep marine environment (Milliman, 1966). Folk (1965) believed that the crystals retain their needle-like shape after inversion, and this was confirmed by the observations of Purdy (1968).

Aggradational recrystallization of the low-Mg calcite needles to subequant polyhedra ("micrite") probably followed inversion (Folk,

1965) and was probably simultaneous with initial recrystallization of fossil tests. Both events were probably late syngenetic. Fractures which cut both the micrite and fossils, but which are obscured in the fossils by further recrystallization, indicate that recrystallization continued in the fossils after it had stopped in the surrounding carbonate.

Aggradational recrystallization of micrite to microspar, and microspar to pseudospar, occurred in many rocks, and is evidenced by continuous gradations from micrite to pseudospar within the rock.

Birdseye structure, vertical borings which cut the birdseye structure, early fracturing of the carbonate muds, and undeformed pellets indicate that the carbonates were cemented early. The presence of unbroken fossils may also be supportive evidence for early cementation of the rock (Shinn et al., 1977). Although some of the ooids show signs of distortion, the paucity of grain-to-grain contacts suggests that distortion predates deposition. Carrozi (1961) noted that distortion can be generated during sedimentation in agitated conditions by reciprocal impacts of ooids at different stages of induration.

Precipitation of Pyrite

Euhedral pyrite was identified in thin sections of cuttings of the Giles Creek at Dingo No. 1 well. The pyrite is closely associated with organic material, which suggests that it formed in locally reducing environments around the organics as they decayed. The precipitation of pyrite was probably early syngenetic.

Dolomitization

Dolomite-filled embayments in pseudospar, inclusions of relict calcite in dolomite rhombs, the preservation of original depositional texture and sedimentary structure in beds of dolostone, and dolomite crystals larger than 0.03 mm (Folk, 1968) indicate that dolomite is a replacement mineral in the Giles Creek and upper Chandler. Evidence suggests that the dolomite formed by seepage reflux of a hypersaline brine (see DOLOMITIZATION), a mechanism which is operable from the surface to depths of about 300 meters (Deffeyes et al., 1965). The range in depths at which replacement can take place by reflux indicates that the event could be either late syngenetic or early anagenetic. Stylolites which cut rhombs of dolomite, however, indicate that dolomitization could not have taken place at exceedingly great depths. The large variation in size of dolomite crystals may be evidence of multiple episodes of replacement. Evidence of much of the early diagenetic history and depositional texture of the carbonates was destroyed in this event.

Early Silicification

Isolated areas of the carbonates have been replaced by microcrystalline or megacrystalline quartz. Quartz-filled embayments in dolomite rhombs and dolomite inclusions in quartz suggest that silicification followed dolomitization. The same sequence was reported by Biggs (1975) in his study of nodular cherts in Illinois, and by Logan and Chase (1961) in their studies of the Moore Group, Western Australia. Fossils and birdseye structure are selectively replaced in some rocks, and in others the replacement is entirely random. Replacement was probably simultaneous with the filling of intragranular voids with quartz (Plate 17). Some of the quartz may have filled pore space developed by dissolution of calcite during dolomitization. The silica may have been derived from alkaline ground waters which migrated through the sediments (Sathyanarayan and Muller, 1980). A decrease in the pH of the environment to 7.8 or lower could cause simultaneous dissolution of dolomite and precipitation of silica. Petrographic evidence and the presence of orange and pink chert in dolostone at Wallaby No. 1 Well indicate that the event was not epigenetic. It is likely that this event was either late syngenetic or early anagenetic.

Compaction

Stylolites are present in a number of samples, and indicate pressure solution of the carbonates (Plate 18). Dolomite rhombs which are cut by stylolites indicate that compaction followed dolomitization, and the lack of quartz in voids within the stylolites may indicate that compaction followed silicification.

Fracturing

Evidence of late fracturing is present in many of the carbonates. The fractures offset the stylolites, indicating that fracturing followed compaction. Fracturing was late anagenetic, and probably occurred during the Alice Springs orogeny.

Oxidation and Filling of Voids with Hematite and Calcite

Many of the fractures and much of the pore space is lined with hematite and filled with radial-fibrous calcite. These minerals are interpreted as epigenetic precipitates from migrating meteoric waters saturated with respect to calcite. The position of hematite between the host rock and the radial-fibrous calcite suggests that oxidation preceded precipitation of calcite. Although most of the secondary porosity was created by fracturing, some is fenestral. The fenestral voids were probably filled with evaporite minerals which dissolved near the present surface prior to precipitation of hematite and calcite. X-ray analysis of cuttings of the Giles Creek at Dingo No. 1 well indicates that anhydrite is present in the subsurface.

Fractures and stylolites were probably convenient conduits for the migrating fluids. Their absence at the time of replacement by silica may explain why the voids were not filled with quartz.

Oxidation of syngenetically precipitated pyrite was also epigenetic, and was probably synchronous with precipitation of hematite in the voids (see ACID-INSOLUBLE RESIDUES, Provenance and Origin). Oxidation of the pyrite produced limonite and hematite, which impart the orange and tan colors to the carbonates in outcrop.

Dedolomitization

The presence of minor amounts of rhombohedral calcite with small rhombohedral dolomite centers suggests that dedolomitization occurred in some carbonates. Evamy (1967) regarded dedolomitization as a near-surface process and suggested that it occurs when dolomite is brought in contact with solutions having a high Ca/Mg ratio. Dedolomitization may have been synchronous with other epigenetic events.

Late Silicification

Epigenetic silicification occurred in some carbonates. The silica is present as microcrystalline, megacrystalline, and euhedral quartz, and preserves original depositional texture (Plate 19). Inclusions of disseminated hematite impart an orange color to the quartz, and indicate that silicification postdated or coincided with oxidation. This event may be related to the development of Tertiary silicrete in the Amadeus Basin.

Mudrocks

Hematite-stained grains of biotite in cuttings from Dingo No. 1 well indicate that oxidation of the mudrocks was not epigenetic. The sediments were probably oxidized while subaerially exposed in the intra-coastal lagoon, following the release of iron by chemical degradation of biotite. Early oxidation is also suggested by rims of hematite which surround grains of quartz and feldspar in Sample 209 (Table 3). Initial diagenesis of the clay minerals was probably simultaneous with oxidation (see MUDROCKS, Provenance and Origin). Grim (1968) stated that alteration of clays is probably greatest as they first enter the marine environment, and continues at a decreased rate thereafter.

Syntaxial quartz overgrowths which envelop hematite-cemented quartz grains in Sample 209 indicate that precipitation of silica followed the formation of hematite. The silica may have been derived from surface groundwaters (Sibley and Blatt, 1976; Blatt, 1979), or from the simultaneous degradation of smectite and other clay minerals. The presence of hematite rims around quartz grains and the depth of burial required for pressure solution of quartz grains suggest that the silica was not generated by pressure solution (Sippel, 1968).

Dolomite-filled embayments in quartz indicates that dolomitization postdates precipitation of silica. If the original intergranular voids were not entirely filled with silica, some of the voids may have initially contained calcite. Calcite is no longer present, however, which suggests that it either never precipitated or was completely replaced by dolomite. Dolomitization of the mudrocks was probably late syngenetic or early anagenetic (see DOLOMITIZATION) and occurred in a reducing, alkaline environment.

Concentrations of hematite at the margins of dolomite rhombs suggest that the dolomite may have initially been ferroan. Iron is accommodated in the dolomite lattice in the ferrous state, but is rejected in the ferric state because of its decreased size. Oxidation of ferroan dolomite drives the iron to the margins of the crystal where it combines with oxygen to form limonite and hematite. Migration of the iron probably took place during epigenetic oxidation of the dolomite.

DOLOMITIZATION

Despite the many mechanisms proposed to account for dolomitization of recent sediments, it appears that only the schizohaline (Badiozamani, 1973; Land, 1973; Hanshaw et al., 1971), the seepage-reflux (Adams and Rhodes, 1960; Deffeyes et al., 1965), and the solution-cannibalization models (Goodell and Garman, 1969) are capable of producing the extensive dolostones common in the geologic record.

Deffeyes et al. (1965) believed that sediments are dolomitized by seepage reflux of dense, hypersaline brines. The brines develop in tidal and supratidal flats by evaporation of seawater. Evaporation promotes precipitation of calcite, anhydrite, gypsum, and halite, which increases the Mg/Ca ratio of the water to values which are in equilibrium with both dolomite and calcite. Further evaporation increases the density of the water, driving it downward and seaward into permeable underlying sediments. The brines displace less dense connate and marine water, and replace calcite with dolomite as they move.

Schizohaline dolomitization takes place in a zone of mixing of meteoric and marine waters below subaerially exposed sediments. Mixing of the waters produces a brackish zone which is undersaturated with respect to calcite and supersaturated with respect to dolomite. The high content of magnesium in seawater raises the Mg/Ca ratio to values well within the stability field of dolomite, which enables the water to dolomitize sediments. Tectonic movement of the sediments, periodic mixing during storms (Folk and Land, 1975) and changes in sea level or climate cause vertical migration of the brackish zone and, thereby, dolomitization of considerable volumes of sediment.

Goodell and Garman (1969) found evidence for dolomitization by solution-cannibalism in Cretaceous through Eocene rocks at Andros Island, Bahamas. They believed that aragonite and high-magnesium calcite in mixed-phase carbonate sediments dissolve under subaerial conditions and enrich interstitial fluids in the rocks with magnesium. Magnesium enrichment raises the density of the fluids, and increased density drives the fluids downward into underlying sediments. The underlying sediments are dolomitized and the sediments above become enriched in calcite. At Andros Island, this produced four sequences of dolomite each capped by a zone of partially dolomitized limestone.

Evidence of extensive tidal flats, pseudomorphs after evaporites in outcrop, abundant anhydrite and minor gypsum in the subsurface (John Gorter, oral communication, 1982), the absence of limpid dolomite crystals (Folk and Land, 1975), and the lack of abundant fresh-water diagenetic features suggest that the Giles Creek and upper Chandler were dolomitized by seepage reflux of hypersaline brines.

In order to produce saturation with respect to dolomite and undersaturation with respect to calcite by the schizohaline model, at least 70% of the mixture must be fresh water (Badiozamani, 1973). Although there is evidence for subaerial exposure of the sediments on tidal flats, it is unlikely that these conditions generated a volumetrically significant lens of fresh water. The presence of calcrete suggests that there were times of protracted subaerial exposure, but under arid or semi-arid conditions. If the sediments had been dolomitized in a zone of mixing caused by rainfall on the mainland, the amount of dolostone should increase shoreward. The ratio of dolostone to total carbonate (Figure 22), however, actually decreases shoreward. The amount of dolostone should also increase with increasing proximity to structural highs (Badiozamani, 1973), such as growth anticlines active during deposition of the sediments. This does not occur in the study area (Figures 2 and 22).

The lack of evidence for protracted subaerial exposure, and the absence of alternating zones of limestone and dolostone suggest that sediments of the Giles Creek and upper Chandler were not dolomitized by solution-cannibalism.

Field and petrographic evidence suggest that algal laminae and algal intraclasts were selectively dolomitized. Selective dolomitization may have occurred as a result of decomposition of the algal material. Gebelein and Hoffman (1973) reported that magnesium ions are organically complexed in algal material, concentrating them at three to four times their concentration in adjacent seawater. The magnesium ions are released as the algal materials decompose, creating a microenvironment which is conducive to dolomitization.

The ratio of dolostone to total carbonate shows that the amount of dolostone increases to the east and southeast, with a local maximum in the Steele Gap area (Figure 22). The trend is also reflected in the carbonate units of the Phillipson Facies: those sections having greater than average amounts of dolostone are in the east, and those having less than average amounts are in the west and southwest (Figures 22 and 23).

Lateral variations in the amount of mudrock and terrigenous-rich carbonate indicate that the amount of terrigenous material is inversely related to the amount of dolostone. Because most of the terrigenous material is composed of silt- and clay-sized particles, an increase in the amount of this material would considerably reduce the permeability of the sediments. Decreased permeability would inhibit the flow of a dolomitizing brine and leave some sediments unaltered.

In the Phillipson Facies, the amount of dolostone in the carbonate units varies with stratigraphic position (Figure 23). The average amount of dolostone decreases from Unit 2 to Unit 4, and increases progressively through Units 5 and 6. The abundance of shale in Unit 4 probably accounts for the low dolostone content of this unit. Interbeds of shale would reduce the permeability of the unit, leaving the sediments less accessible to dolomitizing brines.

John Gorter (oral communication, 1982) reported that the greatest concentrations of anhydrite in the Giles Creek at Dingo No. 1 Well are at the top of the formation. The increase in the amount of dolostone above Unit 4 may be indirectly related to the increase in the amount of anhydrite. The presence of anhydrite implies that the sediments were initially in contact with a potentially dolomitizing brine.

PALEOCLIMATE

The rock types, sedimentary structures, and clay mineralogy of the Giles Creek and upper Chandler suggest that the Amadeus Basin was warm and arid during the Cambrian. The development of calcrete, the preservation of halite, anhydrite, and gypsum (Kinsman, 1966), and the formation and preservation of large quantities of illite and smectite indicate that precipitation and humidity were low. Mud cracks and desiccation-cracked algal laminae indicate that evaporation exceeded precipitation. Mud cracks are abundant in arid climates, but are also common in humid climates which are warm. Algal laminae incorporate large amounts of water, and are completely desiccated only when exposed in areas which are warm or arid. Syngenetic alteration of biotite to hematite suggests that temperatures in the area were warm. The large amount of carbonate in these formations is also indirect evidence of warm temperatures. Today, production of marine carbonate is prolific only in waters which are relatively warm (Wilson, 1975).

Veevers (1976) and Drewery et al. (1974) indicated that central Australia was situated near 20°N latitude during the Middle Cambrian (Kennard, 1981, Figure 16). Assuming that climatic conditions near horse latitudes during the Cambrian were similar to those today, the climate of the Amadeus Basin during the Cambrian must have been relatively warm and arid. If the Amadeus Basin were in tropical latitudes, a humid climate must also be inferred. If, however, the area assumed a more northerly position, it would have had a climate similar to those areas which now lie in the desert latitudes. This may have been the case during the Cambrian, due to descending air masses near 30°N and 30°S latitude. Areas near 20°N latitude lie near the present northern margin of the subtropics, adjacent to present semiarid latitudes.

The presence of kaolinite is inconsistent with a strictly arid paleoclimatic interpretation, unless the kaolinite was derived from a source which lay in more humid latitudes. The major source area for the kaolinite, now located to the west-southwest, was located closer to the subtropics and tropics during the Cambrian.

THICKNESS AND TECTONIC IMPLICATIONS

The thickness of the upper Chandler was measured at 19 locations in the study area. Sections were measured on the south flank of Fergusson syncline, along the north flank of Camel Flat syncline, and at a number of locations in the Phillipson thrust sheet. Sections were also measured by Keith (1974) and the BMR at Ross River Gorge and by the BMR at Wallaby Gap (Table 1). The isopach pattern of the upper Chandler is similar to that of the Giles Creek (Figure 13).

Twenty-four sections of the Giles Creek were measured in the study area. These were supplemented by data from sections measured by others at 17 additional sites (Table 1). The Giles Creek is thickest in the Phillipson Pound, Yam Creek, and Missionary syncline areas, and is thinnest in the Camel Flat area. It reaches a maximum thickness of 383 meters at Wallaby No. 1 well, and a minimum thickness of 103 meters at the North Camel Flat section. Isopach contours define a thick area in the N'Dahla thrust sheet, thin areas over crests of anticlines in the Phillipson thrust sheet, and show southward thinning toward the Camel Flat area, minor thickening in the Rodinga Ranges and southwest Allambi Hills, and southward thinning toward the Pillar Range (Figure 14).

The thickness of the lower unit of the Shannon was measured at 11 locations in the Phillipson thrust sheet and eastern Rodinga Range. Thickness data from eight other locations was supplied by the BMR, Oaks (oral communication, 1982), Pancontinental Petroleum, and Exoil (N.T.) Pty. Ltd. (Table 1). The isopach pattern of the lower unit of the Shannon in the Phillipson thrust sheet is the reverse of that of the Giles Creek and upper Chandler (Figure 21).

Pronounced thinning of the Giles Creek across the crests of Ooraminna, Todd River-Windmill, and Brumby anticlines suggests that the structures were growing during Middle Cambrian time. The pattern is reflected in the total thickness of the Giles Creek (Plate 20; Figure 14) and in the thickness of each unit, except for Unit 3, which appears to thicken in the Yam Creek area (Figures 15 through 20). Thinning of the Giles Creek across the crest of Teresa anticline is obscured by regional thinning to the south. Thickness data also support growth of these structures during deposition of the upper Chandler, except at Teresa anticline. Undisturbed bedding in mudrocks and thinning of both competent and incompetent units across these anticlines indicates that the thinning is depositional and not tectonic. Thinning due to flowage of less competent units would cause disruption of bedding in the mudrocks.

The presence of a seismically defined pillow of salt and a pronounced negative Bouguer gravity anomaly along the axis of Ooraminna anticline suggest that growth of the structure was salt-induced. Growth by the same mechanism is inferred for the Todd River-Windmill and Brumby anticlines. Isolated and overturned outcrops of the Loves Creek Member of the Bitter Springs Formation in the core of Yam Creek anticline suggest that the salt was derived from the Bitter Springs Formation. Because evidence of growth at these anticlines is absent in the underlying Arumbera Formation (Conrad, 1981), it is possible that loading on the Bitter Springs was insufficient to cause major flowage until near the end of deposition of the Arumbera. Alternatively, major flowage of salt may have occurred during deposition of the Arumbera, but the anticlines did not become well defined until the end of Arumbera deposition. Subsequent flowage may have accelerated during the Alice Springs orogeny, and probably continued thereafter at a diminished rate until the present (Oaks et al., 1982).

Considerable southward relative movement along the Hi Jinx thrust fault (Figure 4) is indicated by the marked difference in thickness of the Giles Creek on opposite sides of the fault, and by the juxtaposition of the Eastern Facies on the north with the Phillipson Facies on the south. By contrast, the minor difference in thickness of the Giles Creek on opposite sides of the Rodinga thrust fault (Figure 4) indicates that the amount of southward relative movement was minor, perhaps on the order of one to two kilometers. Minor thickness differences on opposite sides of the Camel Flat thrust fault (Figure 4) indicate that the amount of movement on this fault may also have been minor. Thickness data cannot be used to estimate the amount of relative offset on the N'Dahla thrust fault because of the paucity of data along the northern margin of the Phillipson thrust sheet. Conrad (1981), however, estimated 10 to 15 kilometers of southward relative movement using thickness data from the Arumbera.

Consistent southward thinning of the Giles Creek across the projected trend of the Central Ridge (Figure 4) suggests that the effect of the ridge had diminished by Giles Creek time. Oaks (oral communication, 1982) indicated that the effect of the Central Ridge may have diminished as early as Arumbera time. It is possible that the Central Ridge caused the depositional thinning in the Camel Flat area, but this would require considerable southward displacement of the Camel

Flat thrust sheet. Drag and asymmetry of folding along the Camel Flat thrust fault (Figure 4), however, show that the Camel Flat thrust sheet moved primarily northward, relative to the Central Ridge.

Isopach contours show that the lower unit of the Shannon thickens over the crests of Ooraminna, Todd River-Windmill, Brumby, and Teresa anticlines (Figure 21). Thickening at Ooraminna and Teresa anticlines may be partly due to increased westward intertonguing with the Hugh River Shale. At these and the other anticlines, flowage of the lower unit of the Shannon appears likely. Less competent units tend to move into the crests of structures in order to fill the excess volume created by folding (Dahlstrom, 1977). Dahlstrom observed this at the eastern margin of the Canadian Rockies in folded units containing alternating competent and incompetent beds. An increase in thickness of the lower unit of the Shannon over all four structures and the rate at which the thickening takes place, especially at Teresa anticline, suggest that facies change is the less viable alternative.

The increase in thickness of the third unit of the Giles Creek in the Yam Creek area may be the result of accelerated differential subsidence or the effect of proximity to a paleodistributary (Figure 7).

Thickness inferences in the western Rodinga Range and the Pillar Range are based on subsurface data from the Camel Flat seismic survey. If southward thinning of the Giles Creek continues beyond the Pillar Range, the pattern may reflect approach to the southern basin margin. Gravity and aeromagnetic surveys (Wells et al., 1970) suggest that the present basin margin lies only 40 to 50 kilometers south of the Pillar Range.

Isopach contours in the Camel Flat area show that the area of thinnest deposition approximates the transition from the Phillipson Facies to the Southern Facies. The area may be the boundary between a large subbasin to the north and a subbasin to the south of unknown original extent.

IMPLICATIONS FOR EXPLORATION FOR PETROLEUM

General Statement

The Giles Creek and upper Chandler formations are secondary exploration targets in the northeastern Amadeus Basin. The Giles Creek contained shows of hydrocarbons at Orange No. 1, Alice No. 1, and Wallaby No. 1 wells, and both units are capable of forming effective seals.

Structural Implications

Recognition of Early Cambrian growth structures in the study area considerably enhances the prospectivity of the northeastern Amadeus Basin. Early Cambrian growth structures would trap hydrocarbons which generated and migrated prior to the Alice Springs orogeny, and would reduce the potential for thermal alteration of trapped hydrocarbons by raising reservoir horizons above structural depressions. Source horizons in these areas would also reach oil- or gas-generative phases later than horizons in adjacent synclinal areas, increasing the likelihood that these areas still lie within present-day oil- or gas-generative zones.

Reservoir Potential

Despite the shows of gas at Orange No. 1, the shows of oil (in core) at Alice No. 1, and the shows of oil (in core) and gas at Wallaby No. 1 (Gorter et al., 1982, Enclosure 6), the reservoir potential of the Giles Creek and upper Chandler may be limited. The units are breached at Ooraminna, Todd River-Windmill, Brumby, Yam Creek, and Teresa anticlines, and lack significant amounts of primary and secondary porosity. Commercial quantities of hydrocarbons may have to be reservoired in fractures, which would be developed extensively only along the axes of anticlines or in close proximity to faults.

Rapid coarsening of clastics in the basal unit of the Phillipson Facies increases the reservoir potential of the lower Giles Creek to the west. The unit contains 11 meters of moderately porous sand at Dingo No. 1 well, only 40 kilometers west of outcrops where the unit is composed entirely of calcareous siltstone and silty carbonate. Optimum conditions for primary and secondary porosity in the overlying carbonates may also exist in the west, where dolostone is least abundant. Farther west, however, the carbonates grade laterally into fine-grained clastics of the Hugh River Shale, and lose their reservoir potential entirely.

Source Potential

The source potential of the Giles Creek and upper Chandler is poor in most of the study area. Most sediments are organically very lean, and many were deposited under extremely oxidizing conditions. Although values of up to 2.1% total organic matter (T.O.C. of approximately 1.5%) were recorded for some carbonates, most contain less than 0.8% total organic matter (T.O.C. of approximately 0.5%) and are only marginally capable of generating producible hydrocarbons.

To the north, however, the source potential of the Giles Creek increases markedly. At Ross River Gorge for example, the Giles Creek contains dark, fetid, shallow open-shelf deposits nearly 150 meters thick. Unfortunately the Giles Creek is breached in this area, and is completely eroded farther north. Commercial quantities of hydrocarbons may need to enter the Giles Creek from other sources.

Sealing Potential

Because of the considerable thickness of shale and siltstone, the Giles Creek and upper Chandler may form an effective seal. Their sealing capacity should increase as the Giles Creek intertongues with the Hugh River Shale to the west.

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APPENDICES

Appendix A. Figures

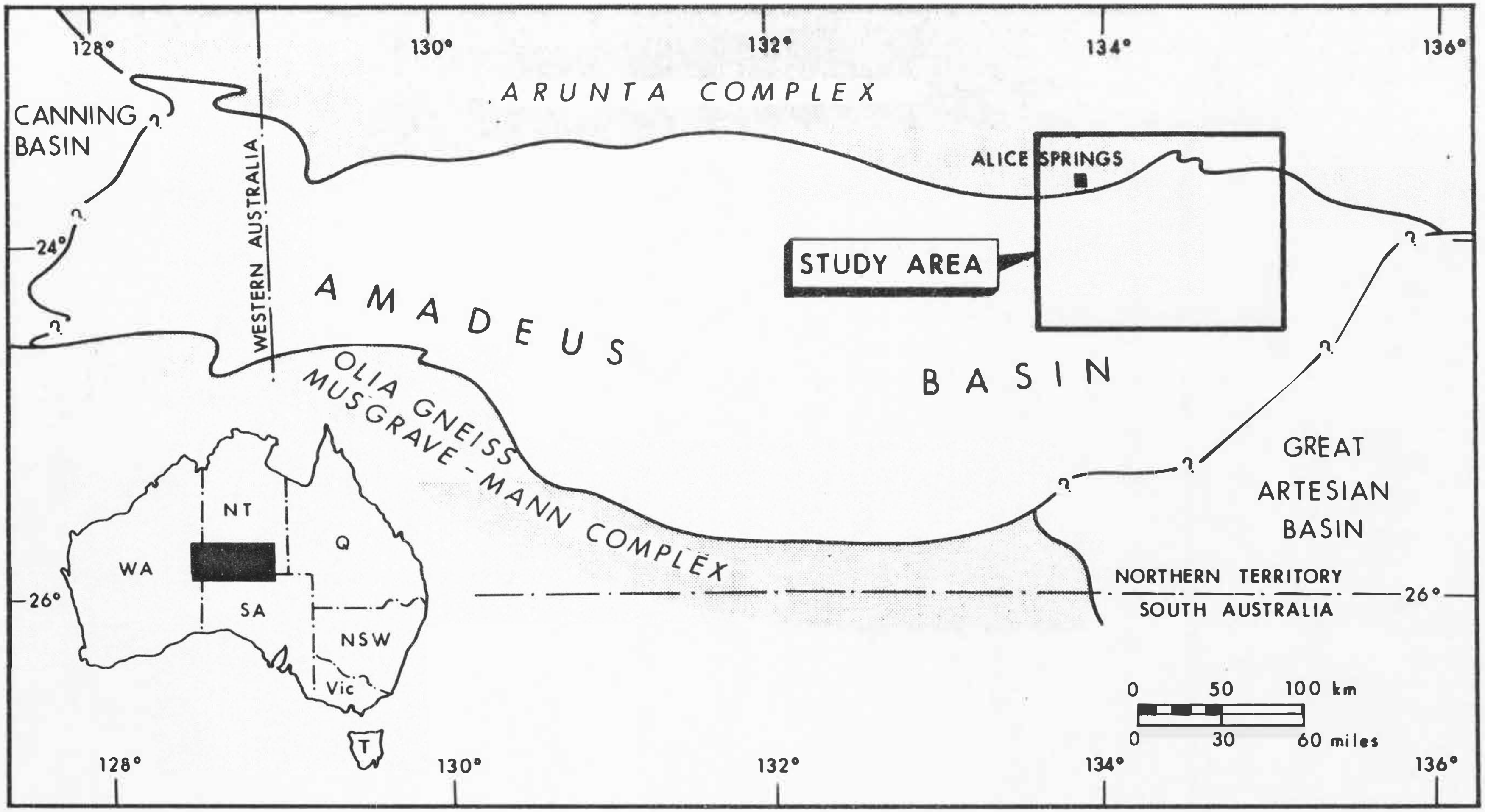

Figure 1. Index map of the Amadeus Basin. Area of study shown in Figure 2 is outlined.

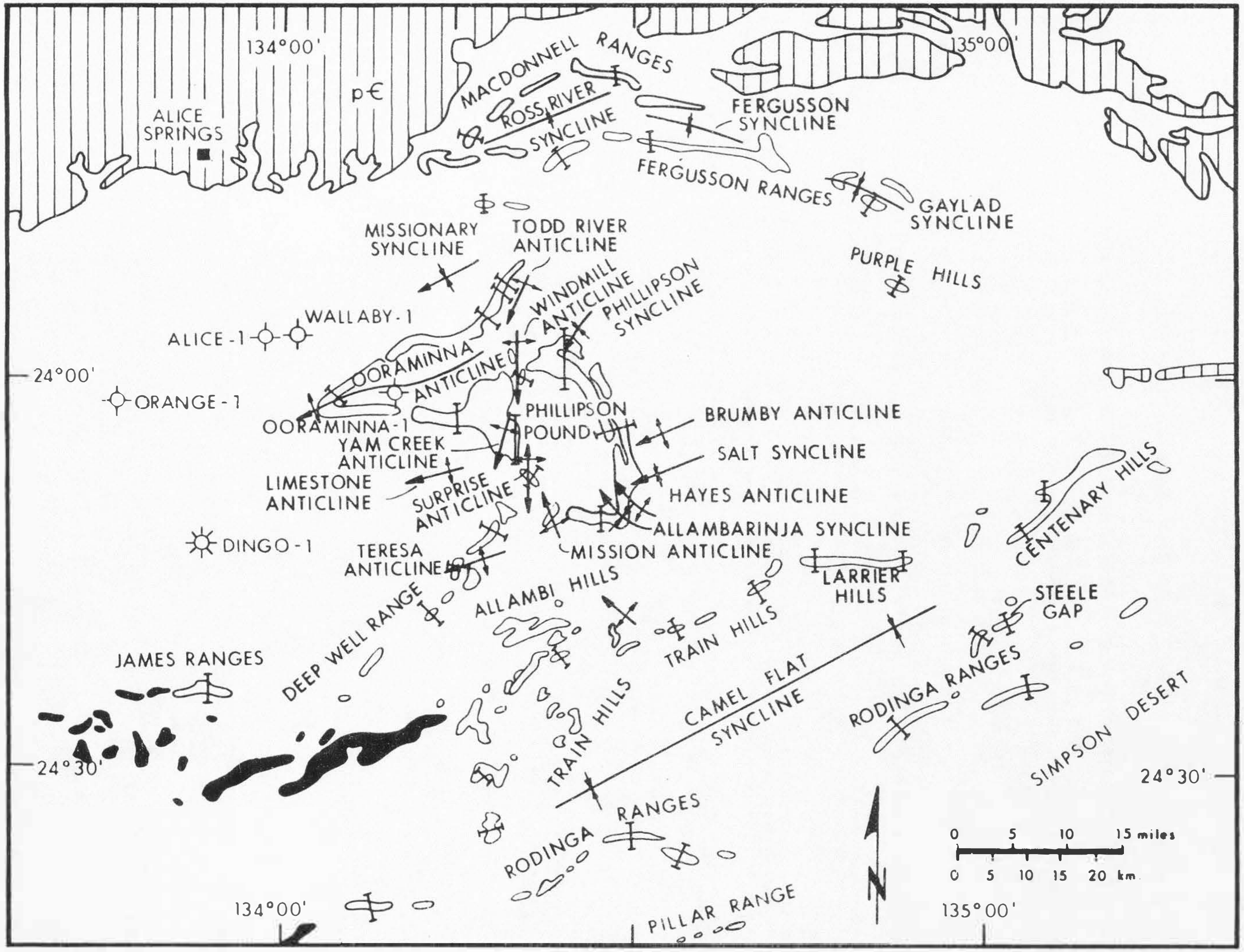

Figure 2. Index map of the study area showing physiographic features, major surface folds, outcrops of the Giles Creek Formation (outlined), outcrops of the "Jay Creek" equivalent (solid areas), the Arunta Complex (lined areas), and the locations of Alice #1, Orange #1, Wallaby #1, Dingo #1, and Ooraminna #1 wells.

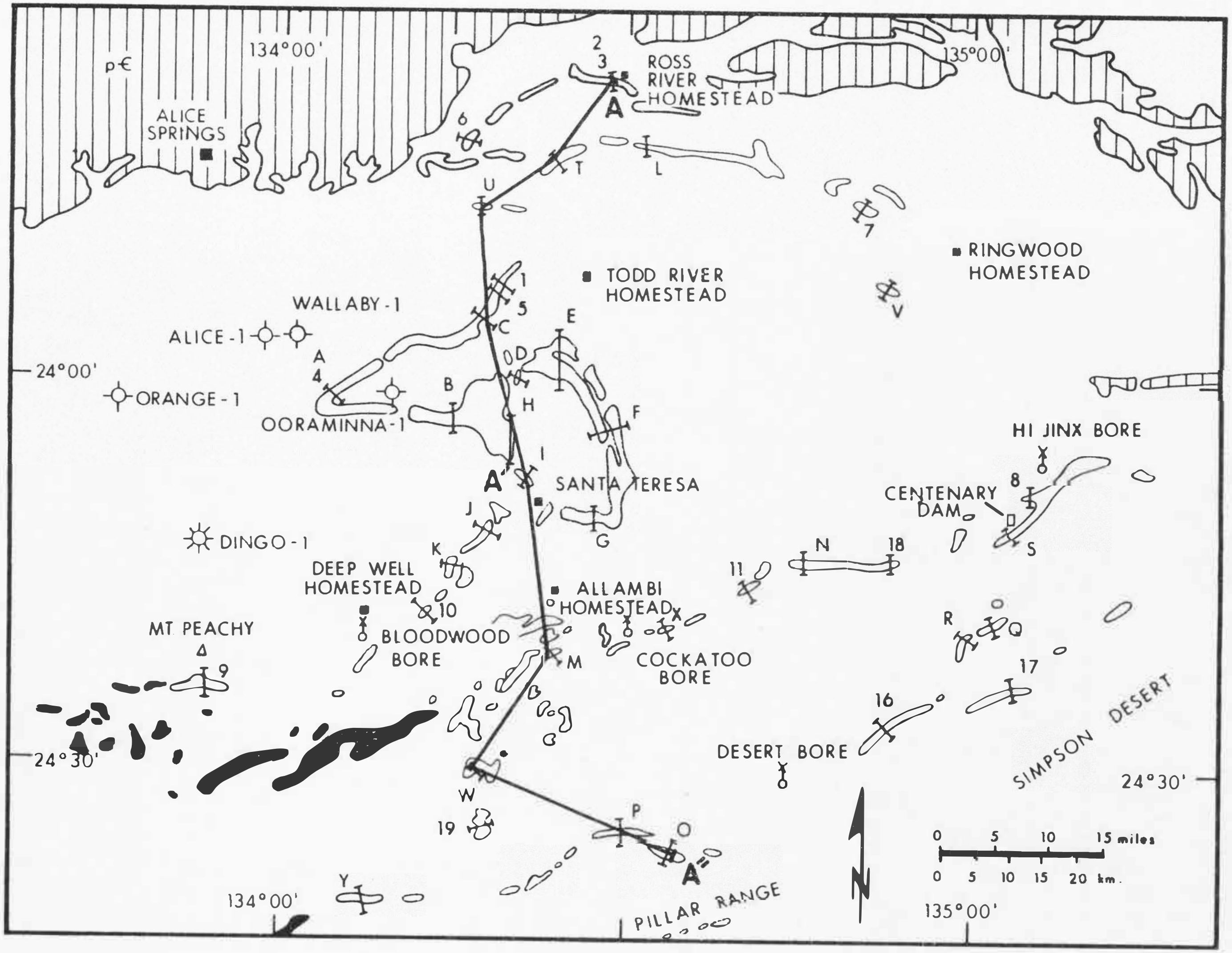

Figure 3. Index map of measured sections and the location of geologic sections A-A' and A'-A".

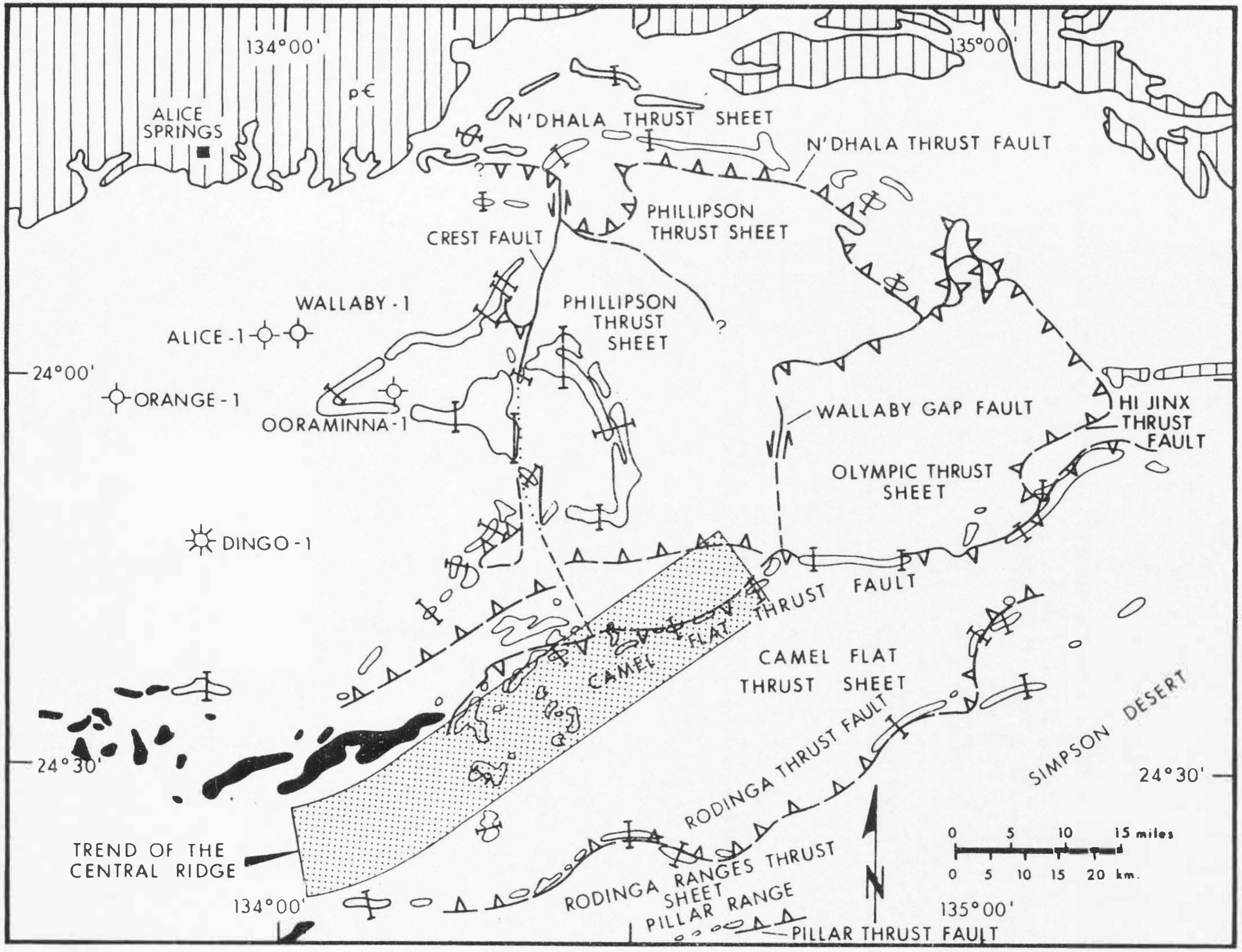

Figure 4. Location of the Central Ridge, thrust sheets, and major faults in the northeastern Amadeus Basin (mapped by R.Q. Oaks).

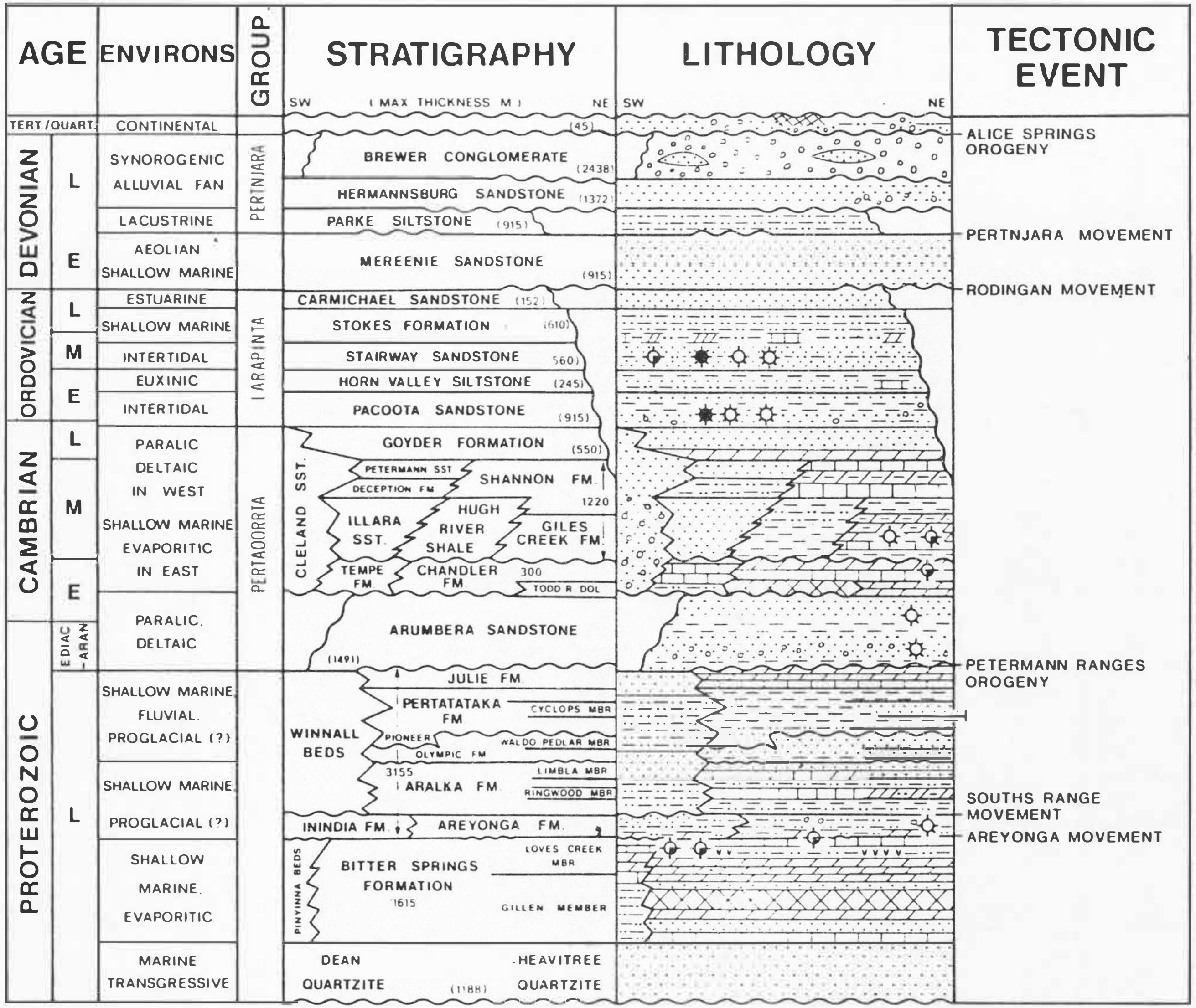

Figure 5. Stratigraphy of the Amadeus Basin.

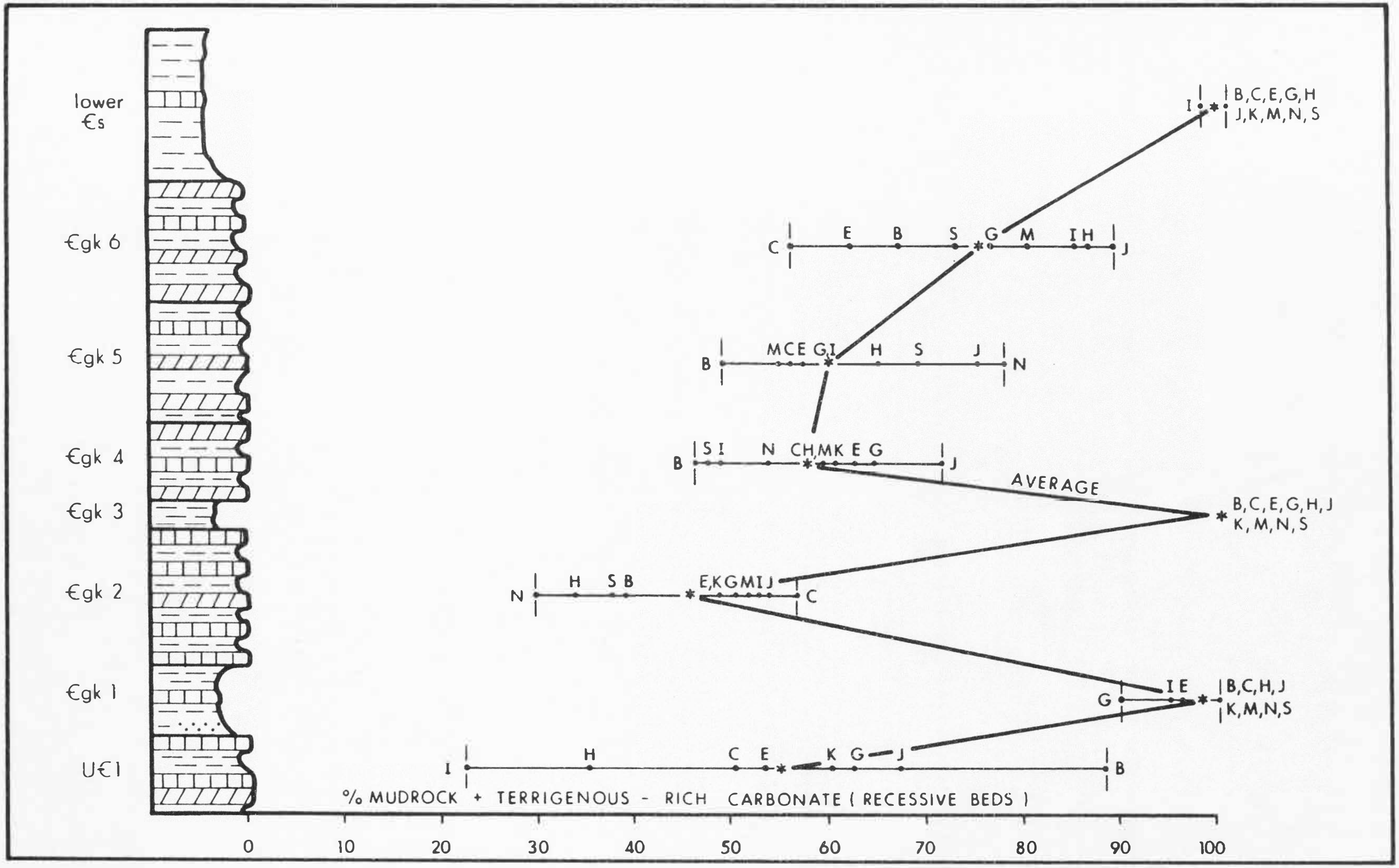

Figure 6. Variation of average percent mudrock plus terrigenous-rich carbonate rock (recessive beds) with stratigraphic position in the upper Chandler, Giles Creek (Phillipson Facies), and lower Shannon formations. Also shown are percent mudrock plus terrigenous-rich carbonate values for each section. Letters designate measured sections (see Table 6).

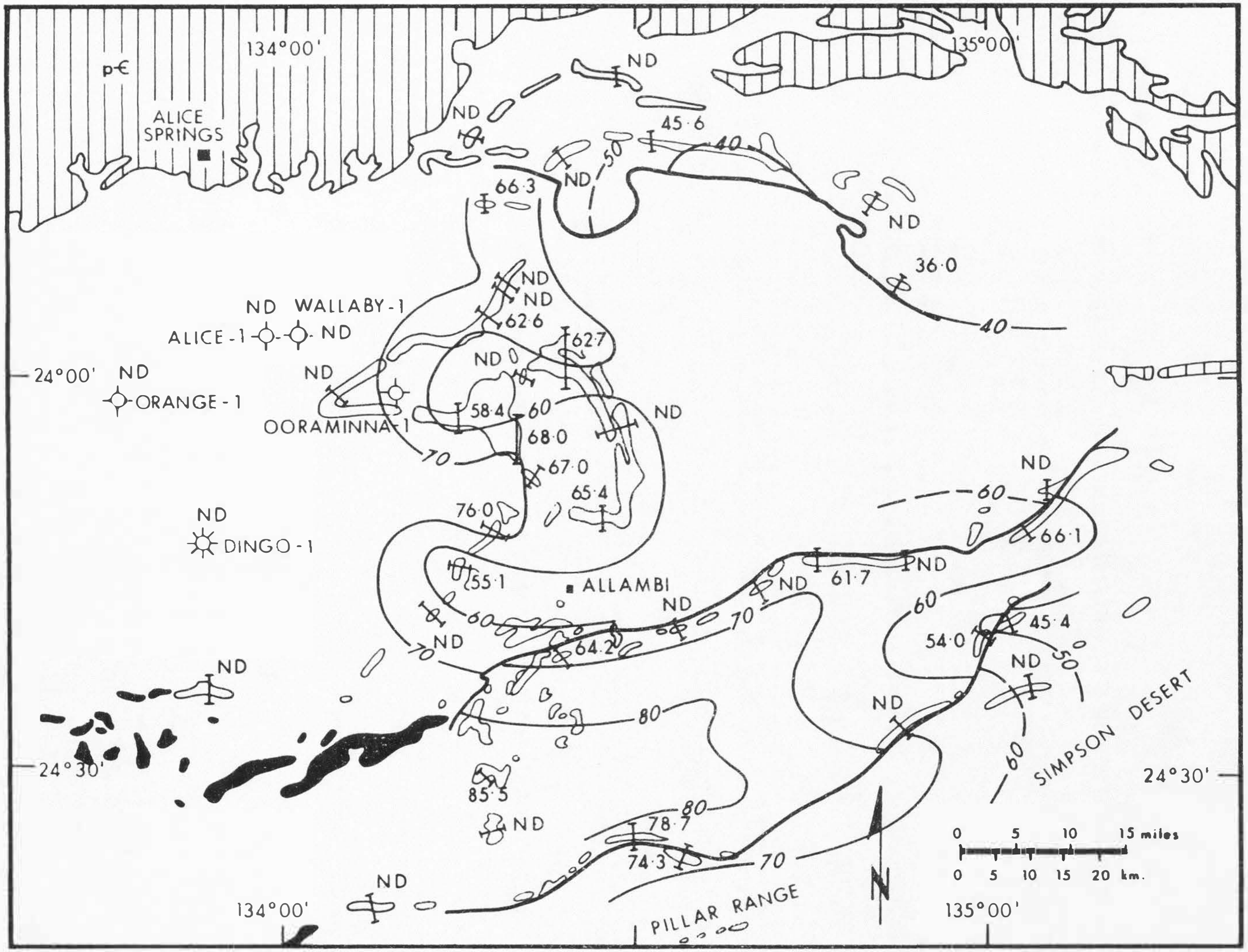

Figure 7. Map showing percent mudrock plus terrigenous-rich carbonate rock (recessive beds) in the Giles Creek Formation, northeastern Amadeus Basin (contour interval = 10 percent).

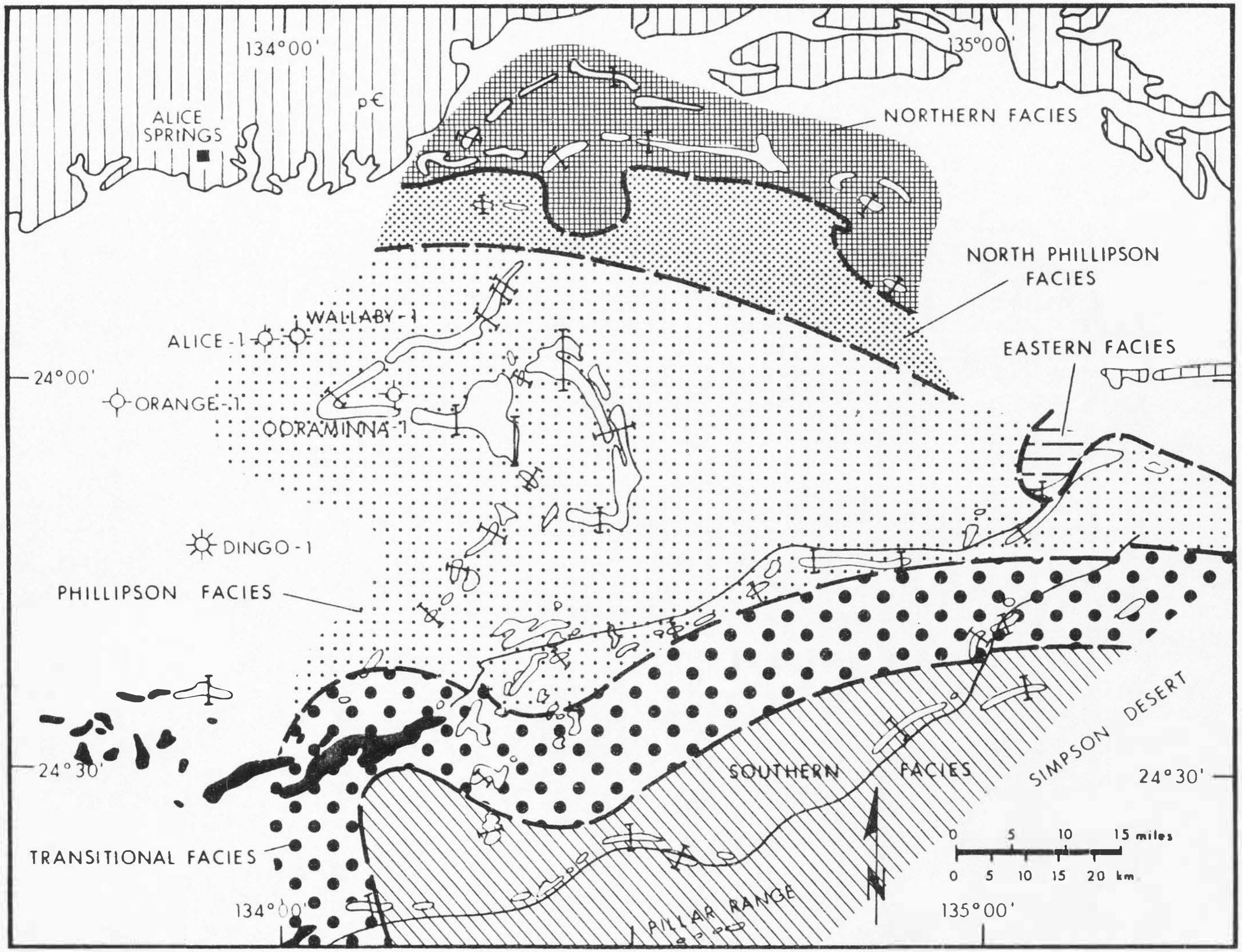

Figure 8. Map showing the lateral distribution of facies of the Giles Creek Formation, northeastern Amadeus Basin.

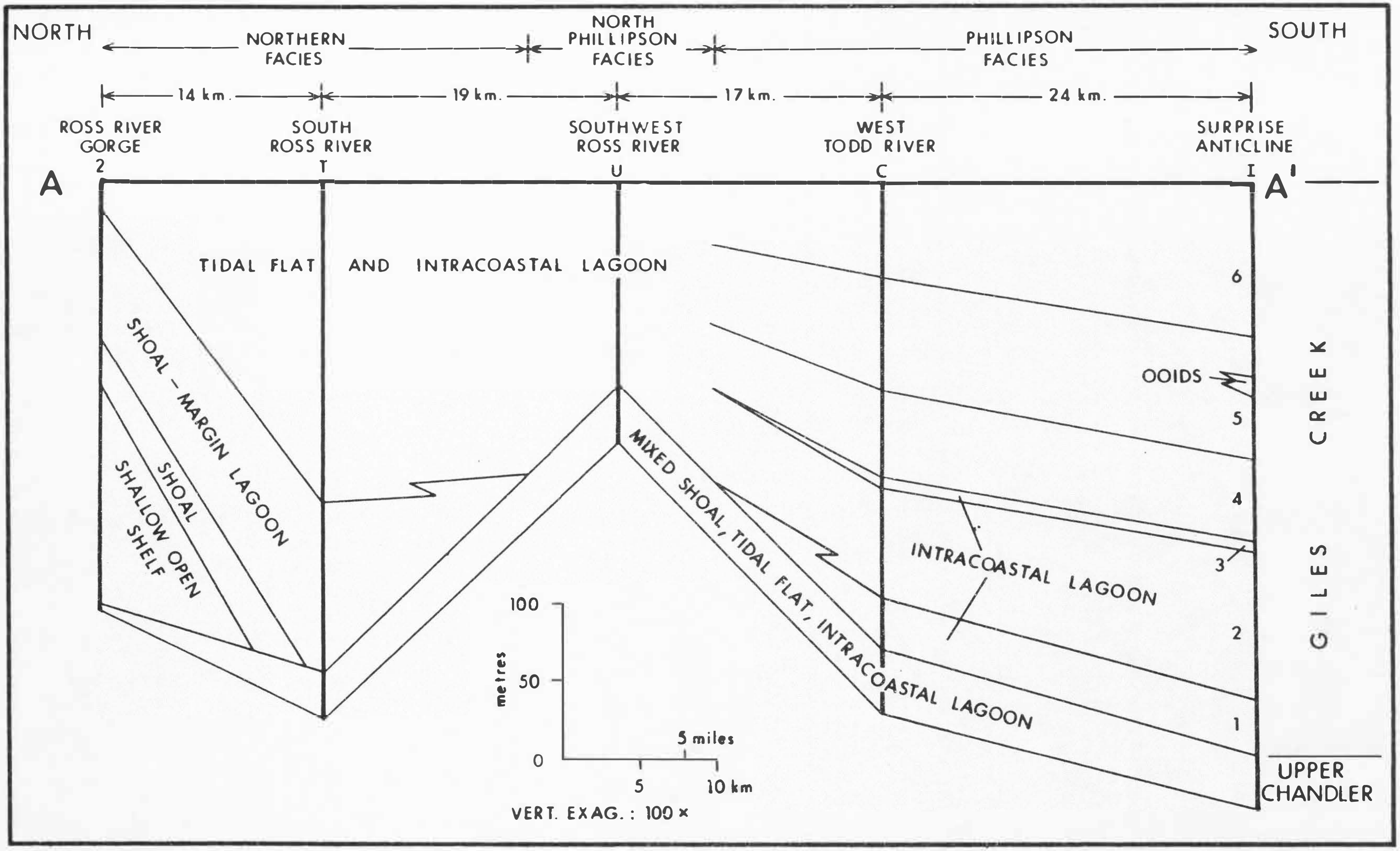

Figure 9. North-south geologic section showing relations of lithofacies in the upper Chandler and Giles Creek formations, northern portion of study area. Palinspastic separation of ten kilometers restored between South Ross River and Southwest Ross River sections [amount of separation estimated from approximate fit of isopach contours of the Arumbera Sandstone (Conrad, 1981)]. Units of the Phillipson Facies are indicated at the Surprise anticline section.

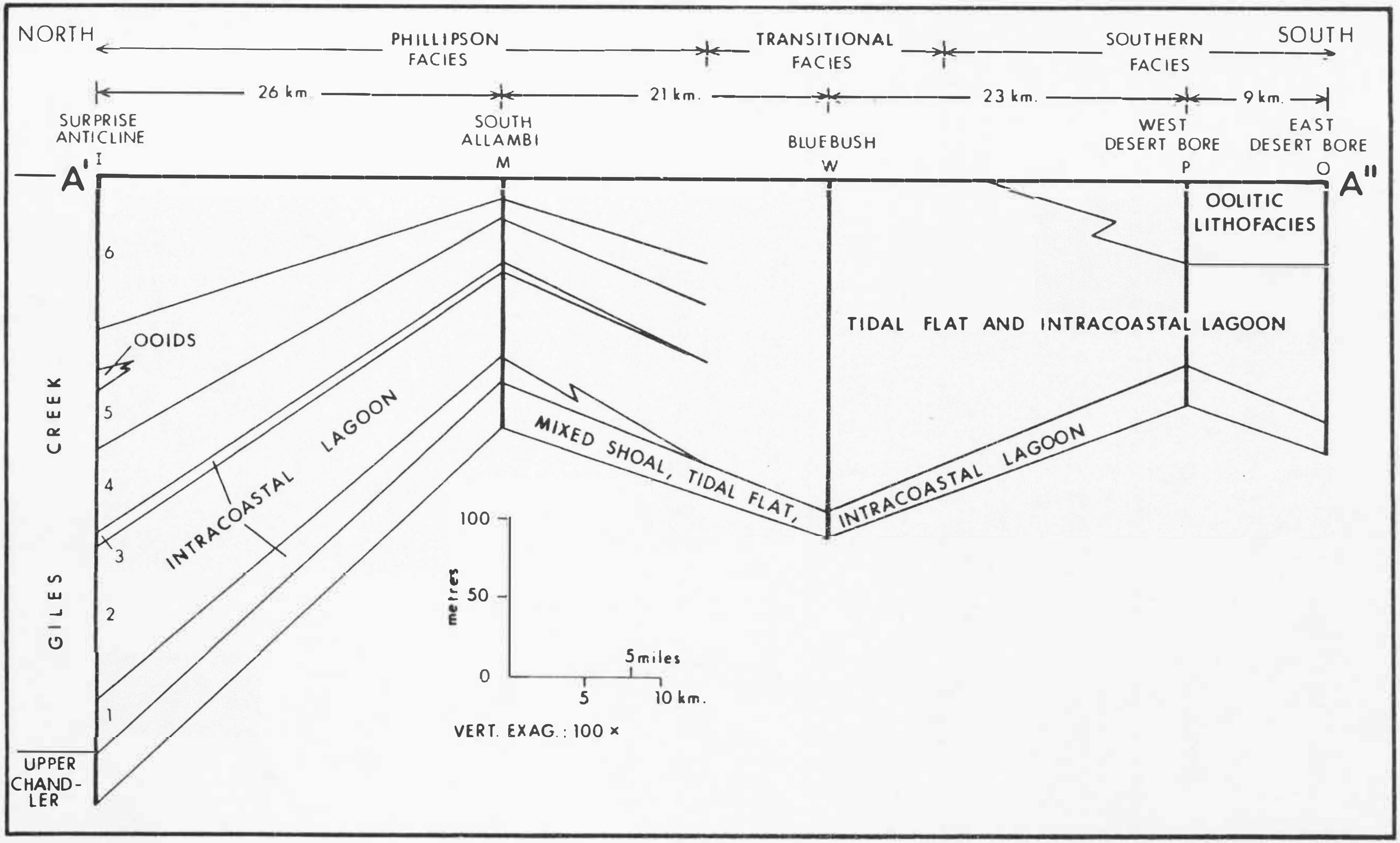

Figure 10. North-south geologic section showing relations of lithofacies in the upper Chandler and Giles Creek formations, southern portion of study area. Units of the Phillipson Facies are indicated at the Surprise anticline section.

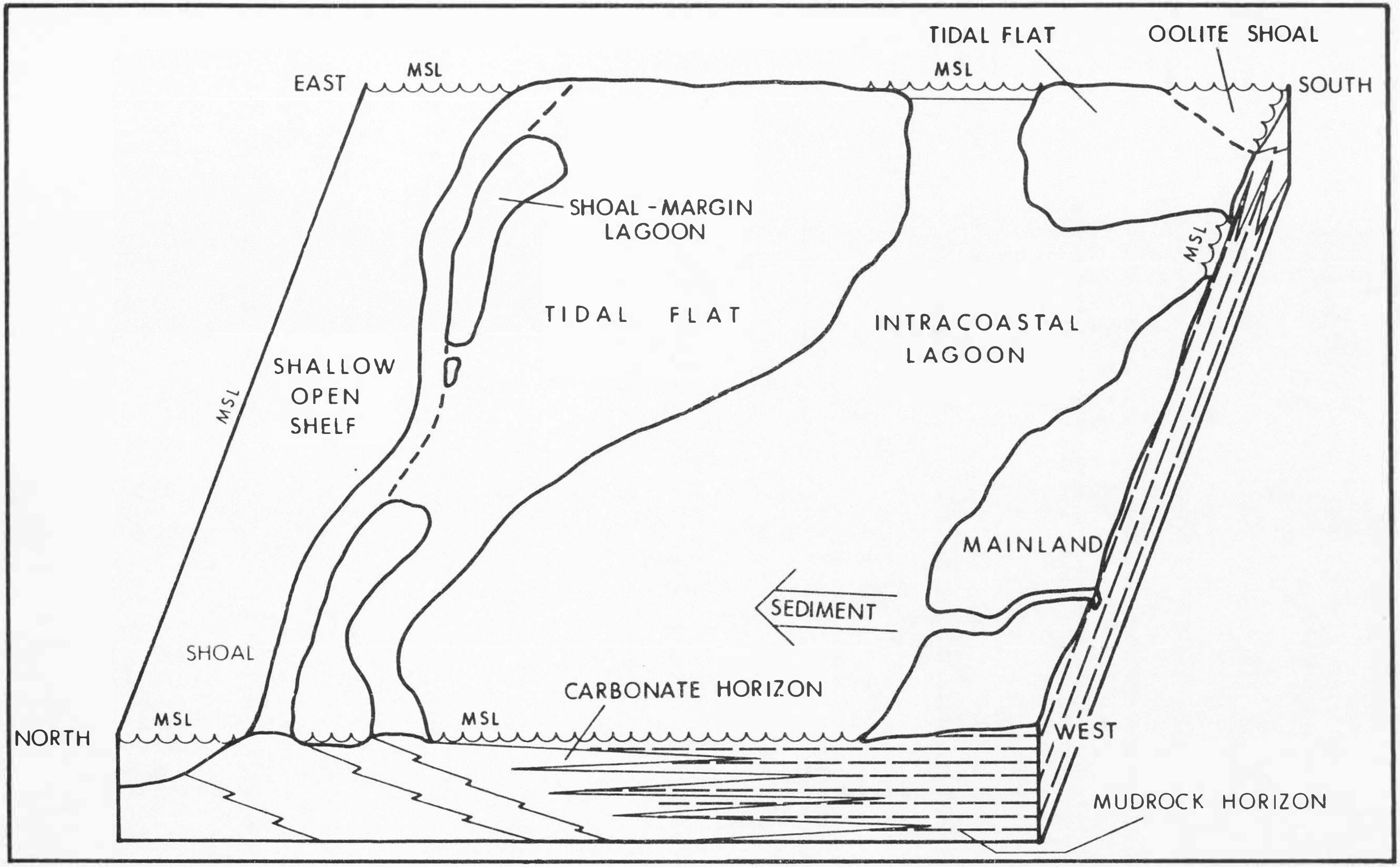

Figure 11. Schematic paleogeographic model showing postulated distribution of lithofacies in late Giles Creek time (Unit 6) with terrigenous influx to the northeast.

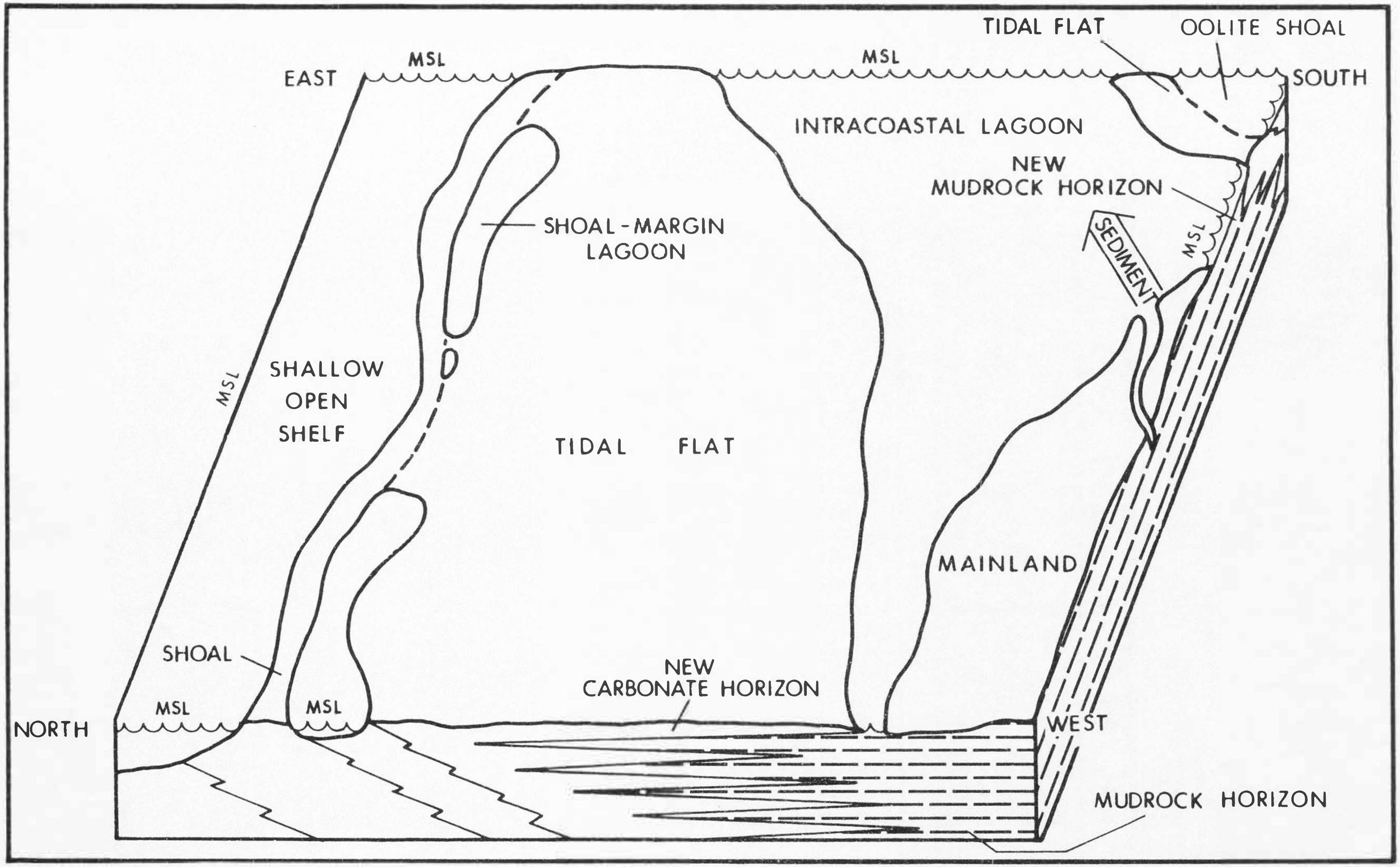

Figure 12. Schematic paleogeographic model showing postulated distribution of lithofacies in late Giles Creek time (Unit 6) with terrigenous influx to the southeast.

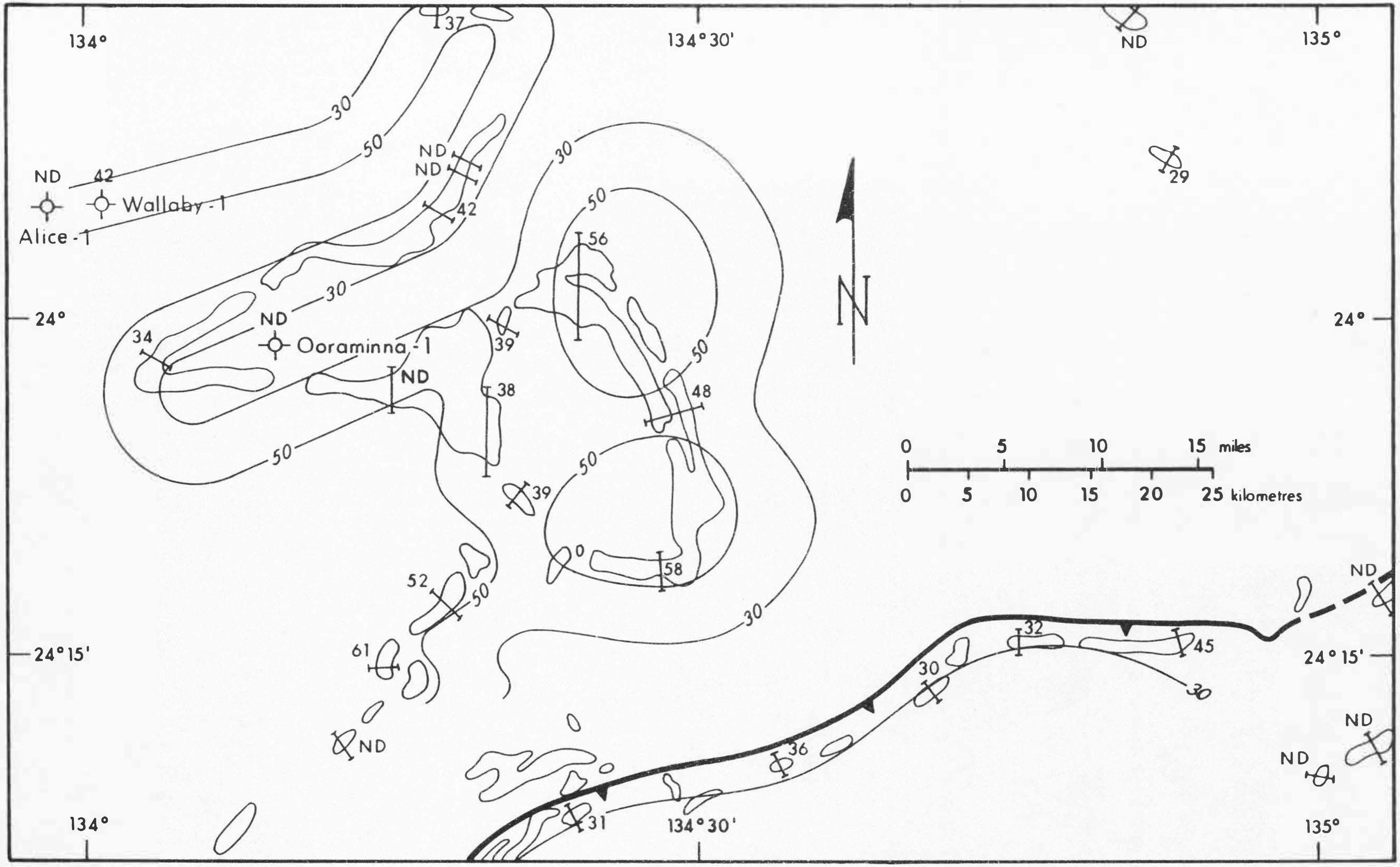

Figure 13. Isopach map of the upper Chandler Formation (contour interval = 20m).

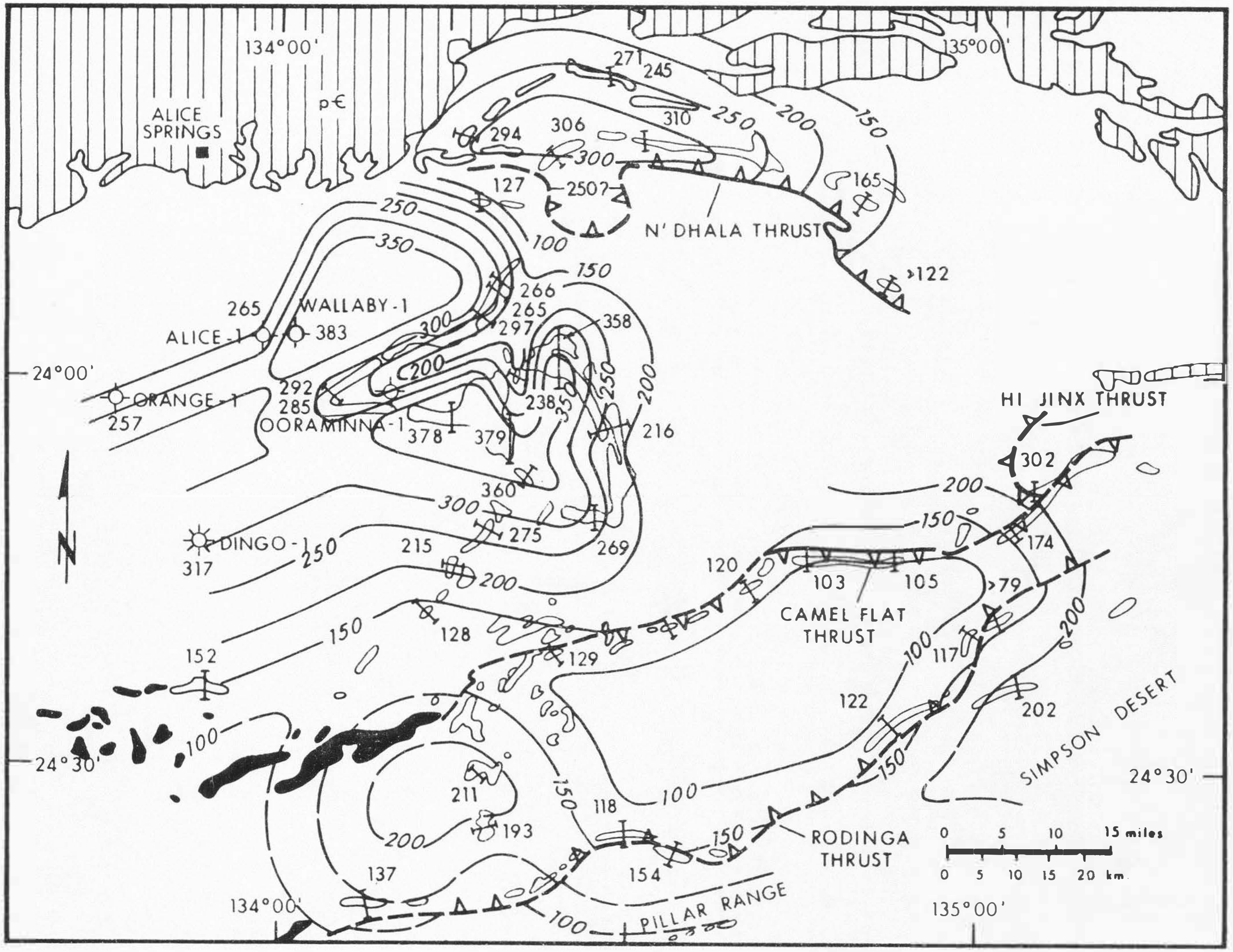

Figure 14. Isopach map of the Giles Creek Formation (contour interval = 50m).

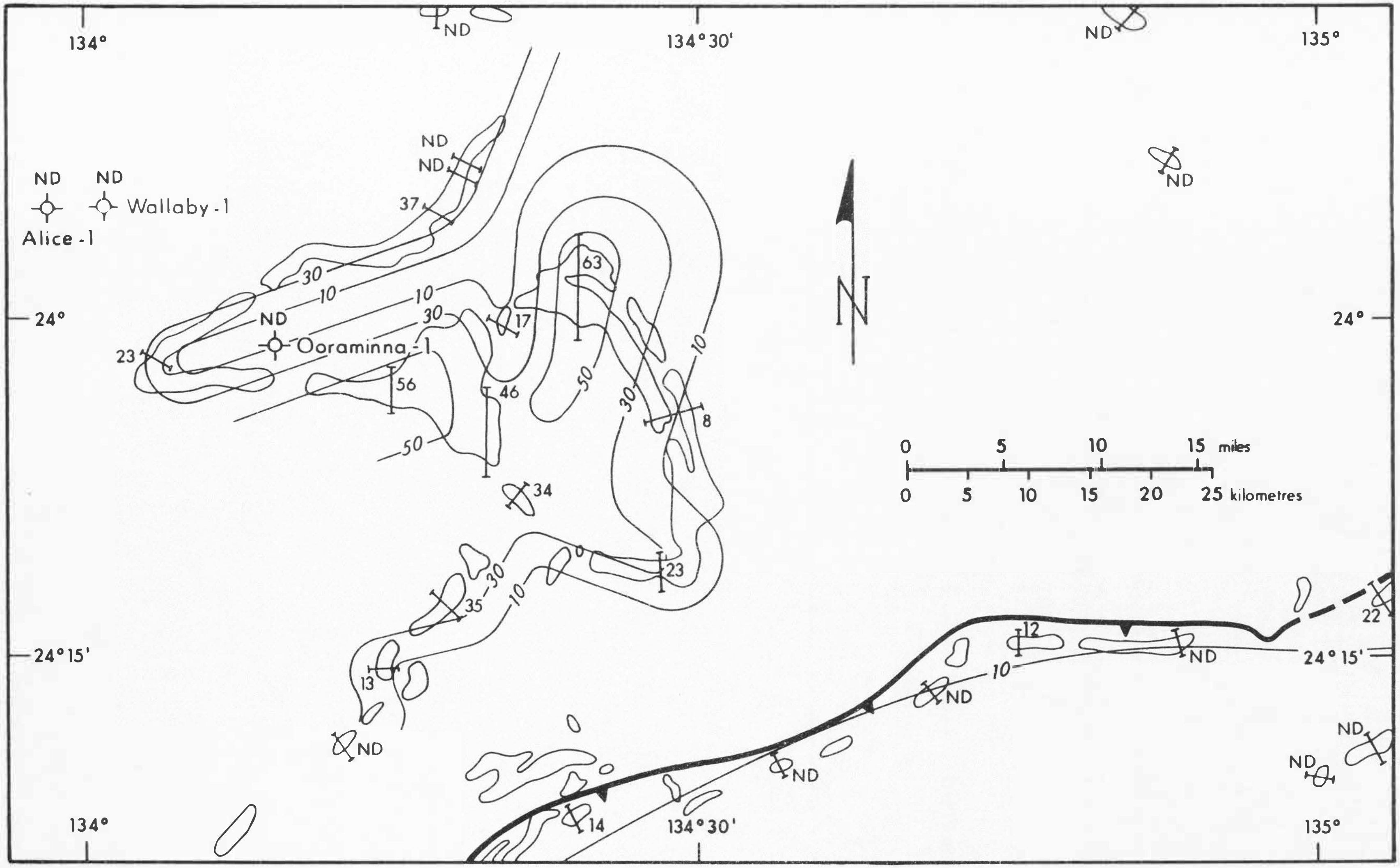

Figure 15. Isopach map of Unit 1 of the Giles Creek Formation (contour interval = 20m).

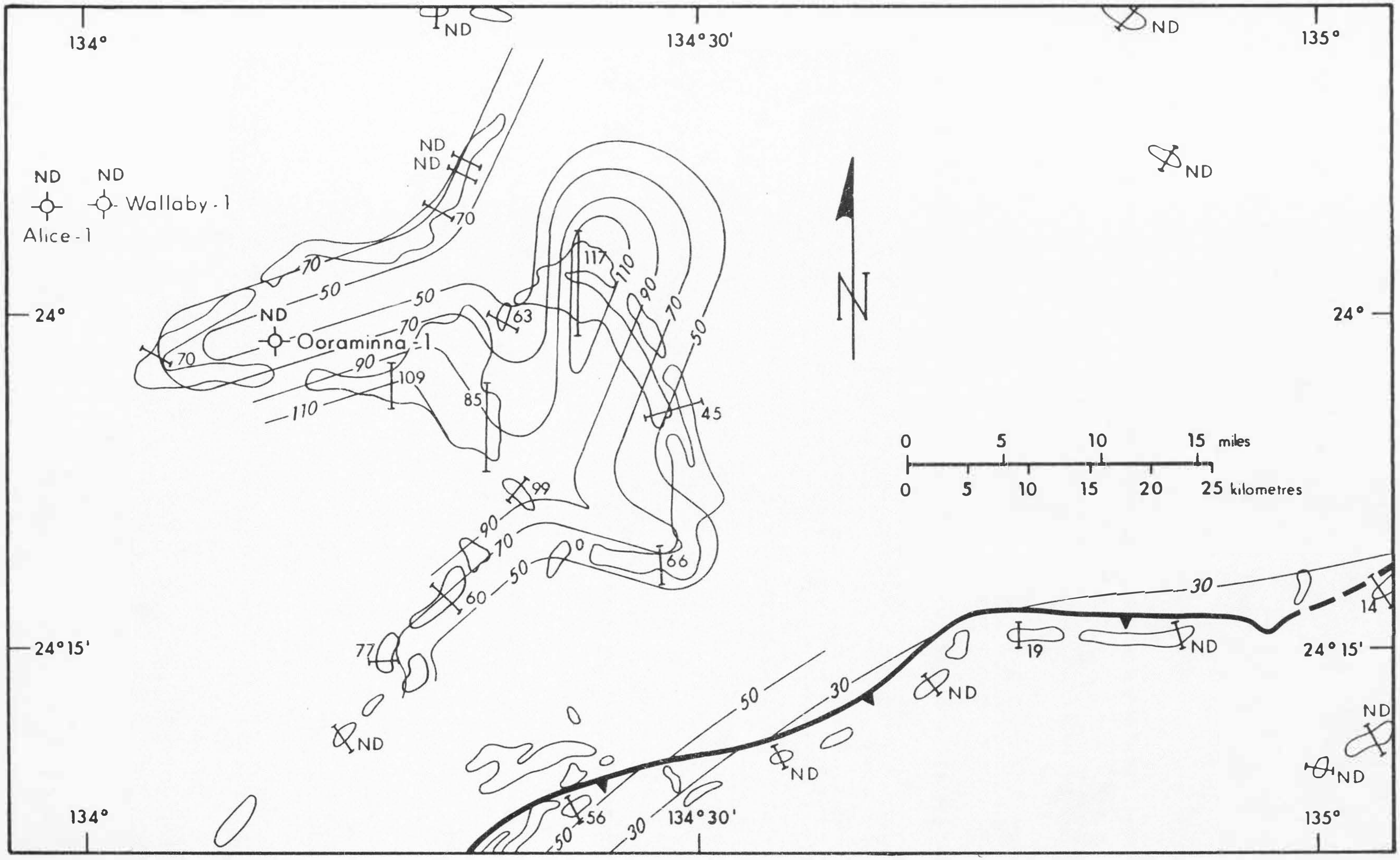

Figure 16. Isopach map of Unit 2 of the Giles Creek Formation (contour interval = 20m).

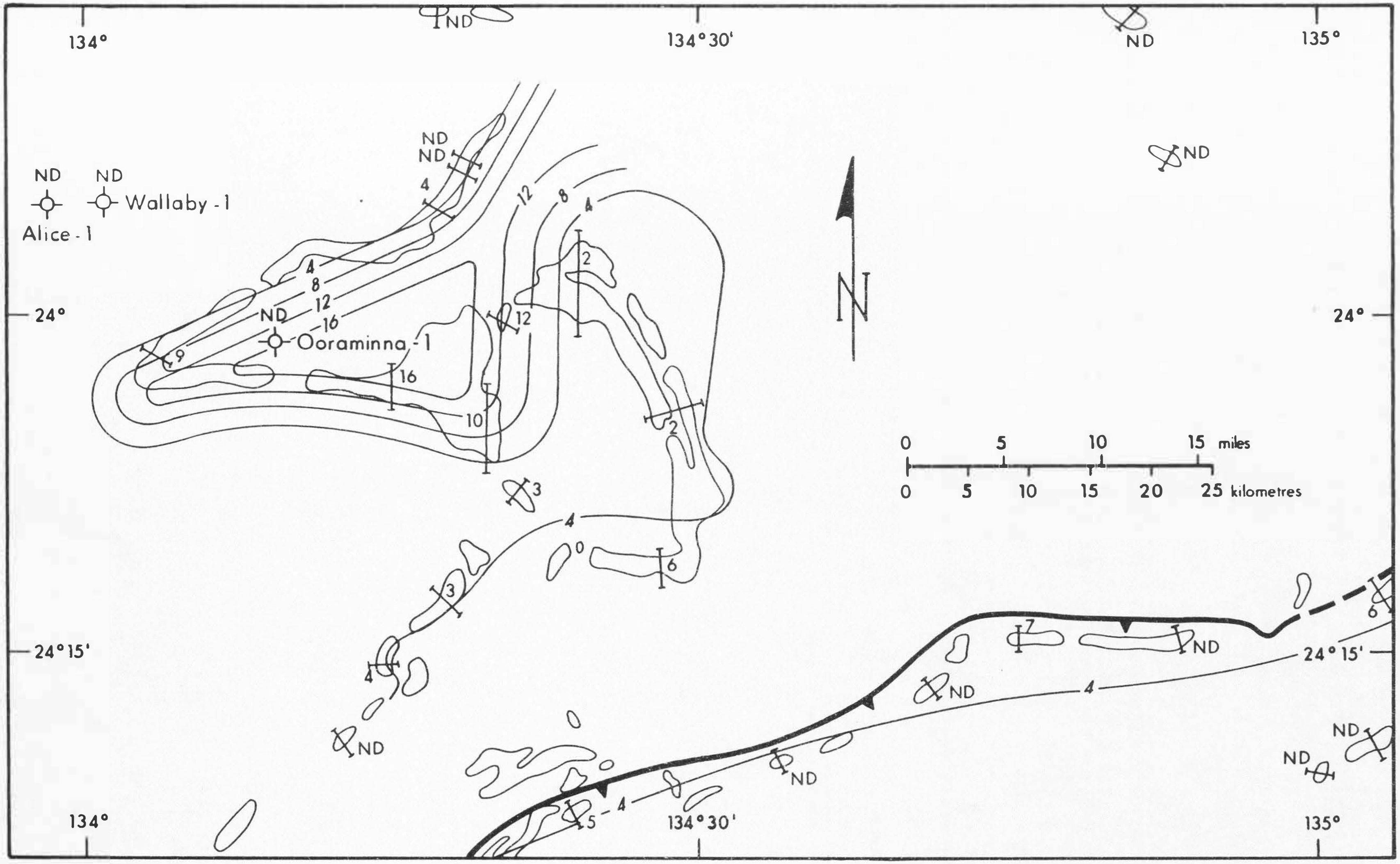

Figure 17. Isopach map of Unit 3 of the Giles Creek Formation (contour interval = 4m).

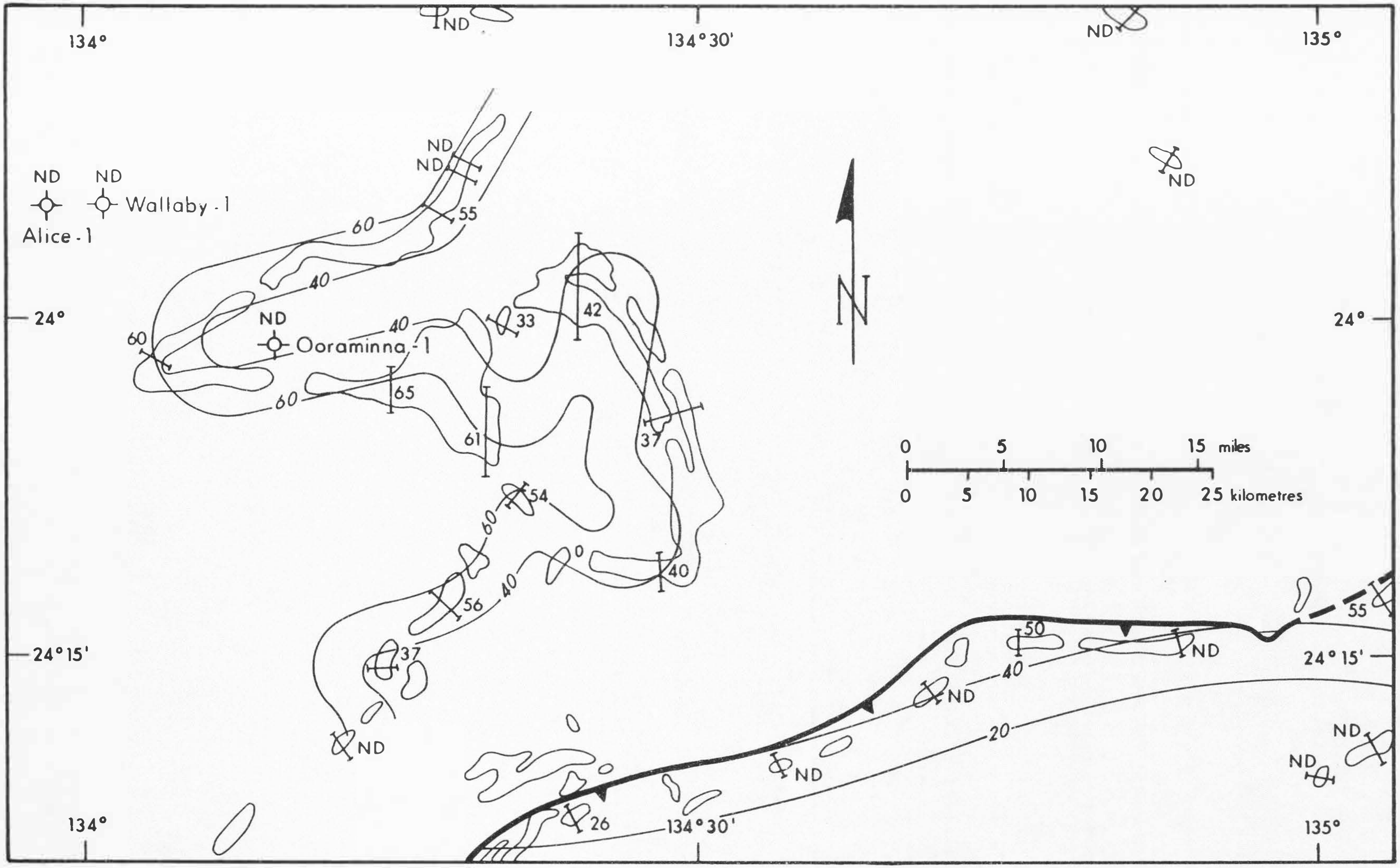

Figure 18. Isopach map of Unit 4 of the Giles Creek Formation (contour interval = 20m).

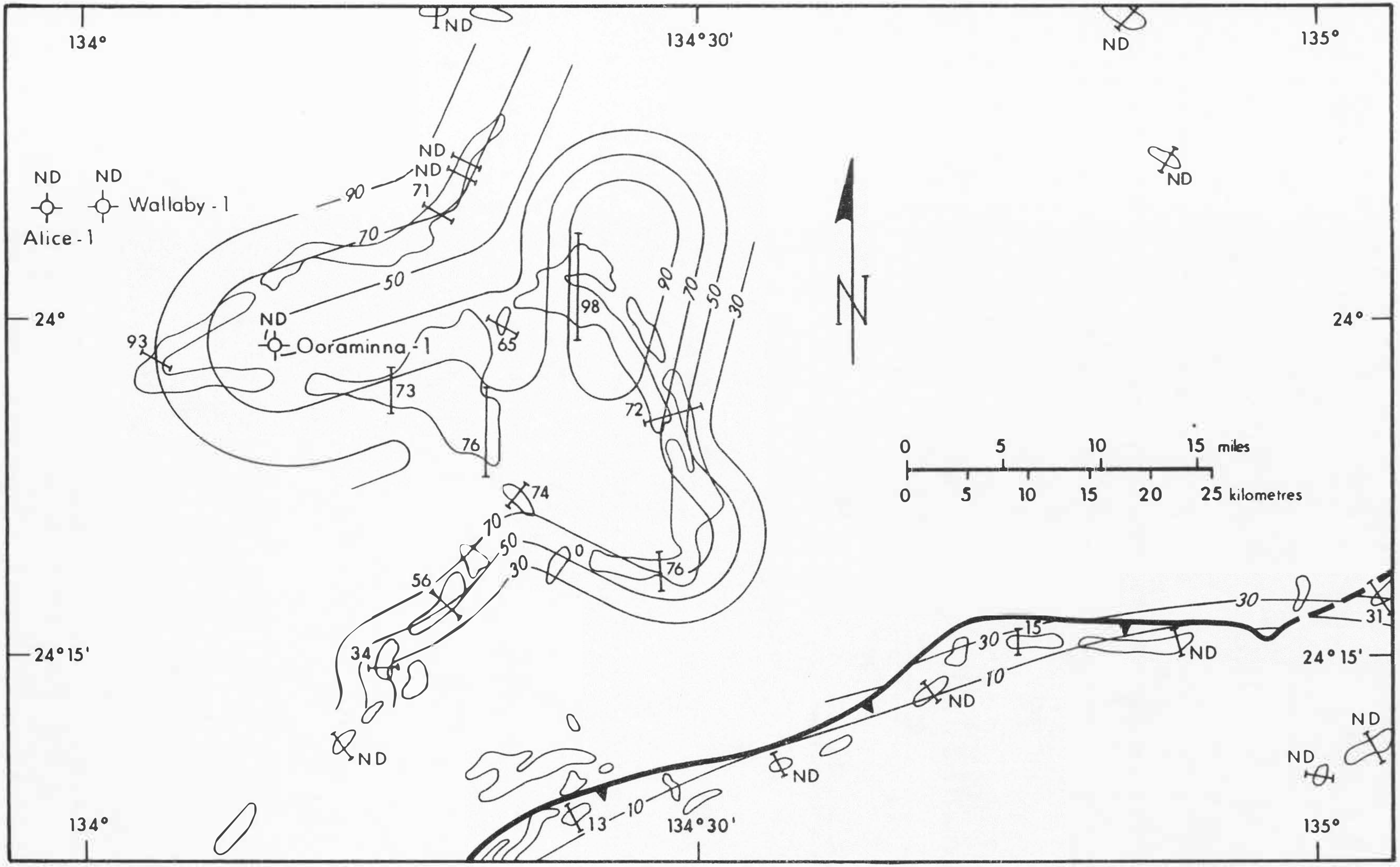

Figure 19. Isopach map of Unit 5 of the Giles Creek Formation (contour interval = 20m).

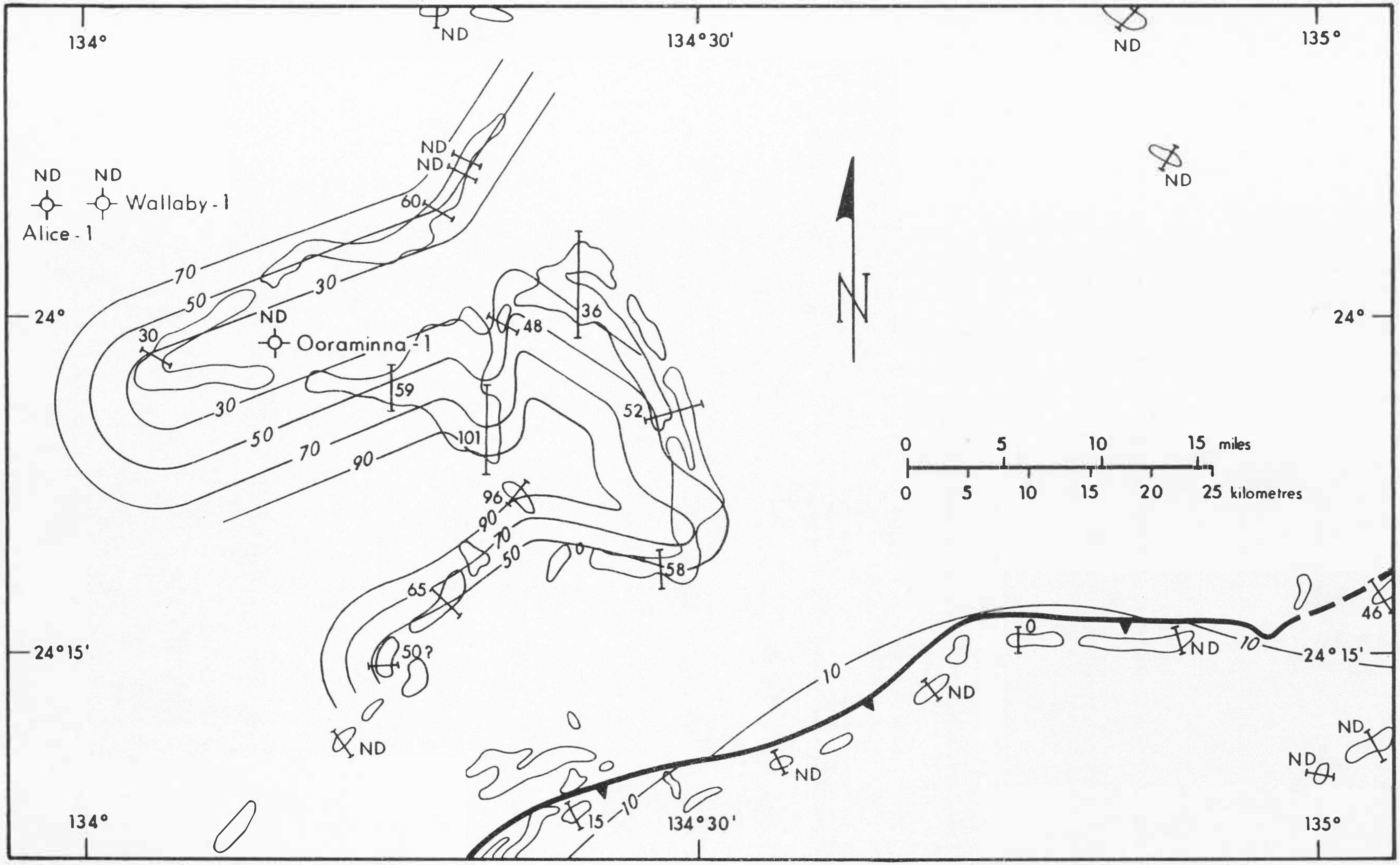

Figure 20. Isopach map of Unit 6 of the Giles Creek Formation (contour interval = 20m).

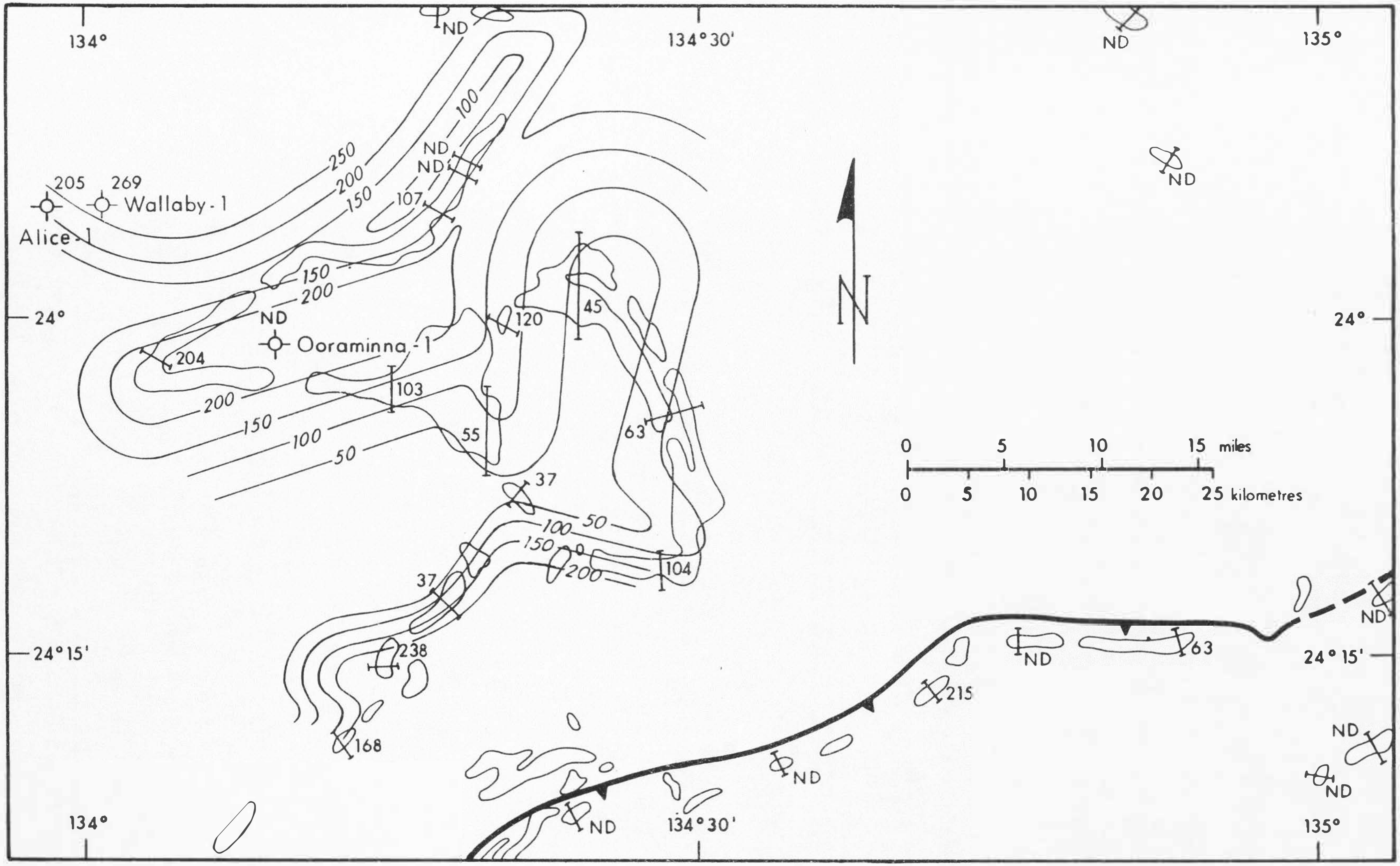

Figure 21. Isopach map of the lower Shannon Formation (contour interval = 50m).

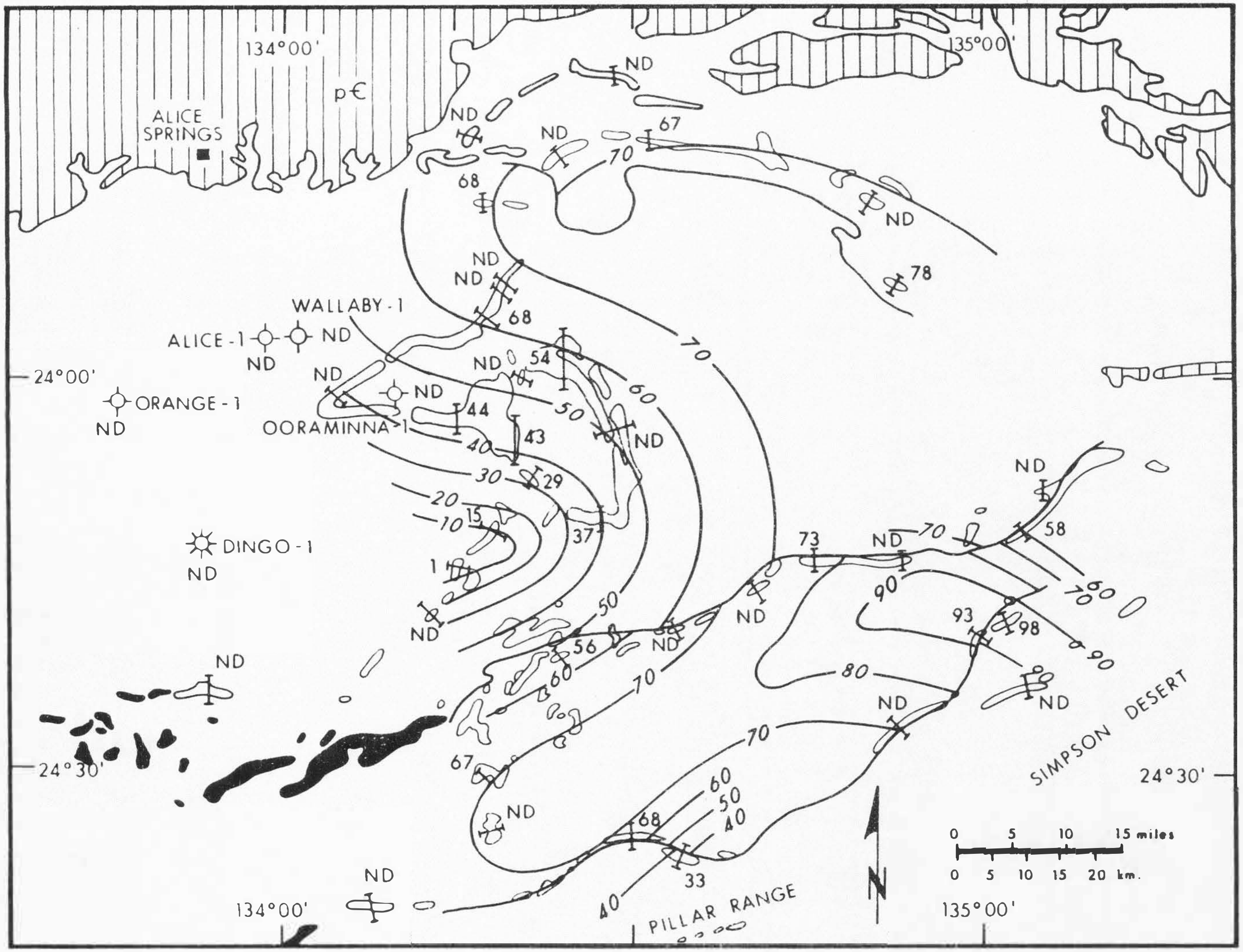

Figure 22. Map showing percent dolostone in carbonate beds of the Giles Creek Formation, northeastern Amadeus Basin (contour interval = 10 percent).

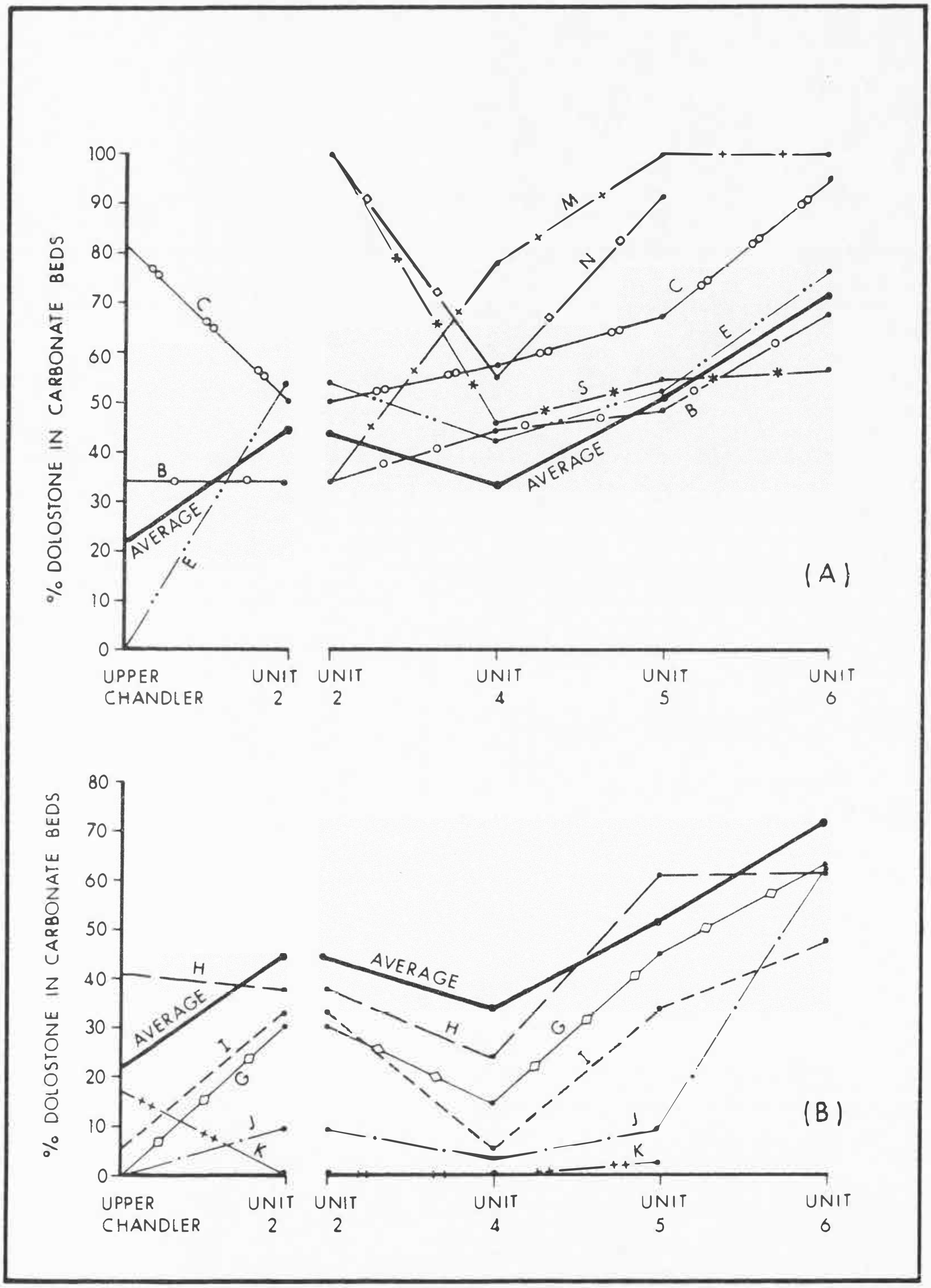

Figure 23. Variation of percent dolostone in carbonate beds with stratigraphic position in the upper Chandler and Giles Creek (Phillipson Facies) formations. (A) Those sections which plot above average, (B) those sections which plot below average. Letters designate measured sections (see Table 1).

Appendix B. Tables

Table 1. Thickness (in meters) of the upper Chandler, Giles Creek, and lower Shannon formations, northeastern Amadeus Basin.

Location	West Ooraminna	Ulta Bank Creek	West Todd River	Windmill Anticline	Phillipson Syncline	Brumby Anticline	South Brumby	Yam Creek	Surprise Anticline	North Teresa	Teresa Anticline	South Fergusson	South Allambi	North Camel Flat	East Desert Bore	West Desert Bore	East Steele Gap	West Steele Gap	Centenary	South Ross River	Southwest Ross River
Section	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
LꞒs	204	103	107	120	45	63	104	55	37	37	238	-	-	-	-	-	-	-	-	-	-
Ꞓgk(total)	285	378	297	238	358	216	269	379	360	275	215	310	129	103	154	118	79	117	174	306	127
Ꞓgk 6	30	59	60	48	36	52	58	101	96	65	50?	-	15	0	-	-	-	-	46	-	-
Ꞓgk 5	93	73	71	65	98	72	76	76	74	56	34	-	13	15	-	-	-	-	31	-	-
Ꞓgk 4	60	65	55	33	42	37	40	61	54	56	37	-	26	50	-	-	-	-	55	-	-
Ꞓgk 3	9	16	4	12	2	2	6	10	3	3	4	-	5	7	-	-	-	-	6	-	-
Ꞓgk 2	70	109	70	63	117	45	66	85	99	60	77	-	56	19	-	-	-	-	14	-	-
Ꞓgk 1	23	56	37	17	63	8	23	46	34	35	13	-	14	12	-	-	-	-	22	-	-
UꞒl	34	-	42	39	56	48	58	38	39	52	61	31	31	32	18	24	-	-	-	-	37
FACIES	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	NF	PH	PH	SF	SF	TR	TR	PH	NF	NF

Table 1. Continued.

Location	Ringwood	Bluebush	Cockatoo	Mt. Charlotte	West Todd River[1]	Ross River Gorge[1]	BMR, Ross River Gorge[2]	BMR, West Ooraminna[2]	BMR, West Todd River[2]	BMR, Williams Bore[2]	BMR, Gaylad Syncline[2]	BMR, Hi Jinx[2]	BMR, Mt. Peachy[2]	BMR, Deep Well Range[2]	BMR, SW Wallaby Gap[2]	MPAL, Orange #1[2]	Exoil, Alice #1[2]	Pancon, Wallaby #1[3]	Pancon, Dingo #1[3]	South Camel Flat[4]	North Simpson[4]	Larrier Hills East[5]	East Jackawarra[5]
Section	V	W	X	Y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
LЄs	-	-	-	-	-	-	0	-	-	-	-	27	-	168	215	-	205	269	239	199	-	63	-
Єgk (total)	>122	211	-	137	266	271	245	292	265	294	165	302	152	128	120	257	265	383	317	122	202	105	193
Єgk 6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Єgk 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Єgk 4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Єgk 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Єgk 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Єgk 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UЄl	29	16	36	-	-	5	8	-	-	-	-	-	-	-	30	-	-	42	0	-	-	45	-
FACIES	NF	TR	PH	TR	PH	NF	NF	PH	PH	NF	NF	EF	PH?	PH	SF?	PH	PH	PH	PH	SF	SF	PH	TR

[1]Data from J. W. Keith (1974)
[2]Thickness interpreted from BMR data
[3]Data from Pancontinental Petroleum (oral communication)
[4]Measured by Robert Q. Oaks, Jr.
[5]Estimated from aerial photographs based on measured dips across nearly flat topography; section 18 crops out at the north end of seismic line MCF-81-05
- designates that no data were obtained

Table 2. Color, rock name, weight percent and composition of acid-insoluble residue, and weight percent of organics in carbonate and chert[1] samples of the Giles Creek and upper Chandler formations.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7]		Acid-Insoluble Residue[8]	
					Whole Rock	Insoluble Residue	Weight %	Composition[9]
6	A	2.4	96	grayish pink silty dolostone[5]	0.8	3.2	24.8	illite (micas), K-feldspar, quartz, smectite, kaolinite, plagioclase, pyrophyllite(?)
6	H	11.1	103	very pale orange silty dolostone[5]	1.7	4.0	42.4	quartz, illite (micas), K-feldspar
-	L	263.8	83	grayish pink silty dolostone[5]	0.2	0.4	45.5	quartz, smectite, illite (micas), kaolinite, K-feldspar, plagioclase
5	A	31.6	97	pinkish gray silty dolostone[5]	0.7	1.8	39.7	quartz, illite, plagioclase, K-feldspar, smectite, kaolinite

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight% Organics[7]		Acid-Insoluble Residue[8]	
					Whole Rock	Insoluble Residue	Weight %	Composition[9]
5	B	72.4	25	light brownish gray, very fine crystalline dolostone	1.2	8.8	13.6	quartz, smectite, illite, K-feldspar, (limonite), (hematite)
5	B	54.0	22	pale red, very fine to medium crystalline calcitic dolo-stone, strongly dolomitized	0.4	15.4	2.6	quartz, K-feldspar, illite, smectite, (limonite), (hematite)
5	B	50.2	21	grayish orange pink, very fine to coarse cry-stalline pellet-bearing algal-intraclast-rich dolomitic lime wackestone, strongly dolomitized	0.6	10.9	5.5	quartz, K-feldspar, illite, smectite, (limonite), (hematite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7]		Acid-Insoluble Residue[8]	
					Whole Rock	Insoluble Residue	Weight %	Composition[9]
5	B	48.0	38	pale red, calcitic medium crystalline dolostone	0.5	20.8	2.4	quartz, illite, smectite, K-feldspar, (limonite), (hematite)
5	B	42.5	19	grayish red, silty crystalline dolostone	-	-	9.9	quartz, illite, smectite, K-feldspar, (limonite), (hematite)
5	B	32.5	18	pinkish gray, silty crystalline dolostone	-	-	21.1	quartz, illite, K-feldspar
5	B	14.2	15	light brown, very fine to coarse crystalline pellet-bearing cryptalgalaminated calcitic dolomite boundstone, strongly dolomitized	0.1	1.7	5.9	quartz, K-feldspar, illite, smectite, kaolinite, (limonite), (hematite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7] Whole Rock	Weight % Organics[7] Insoluble Residue	Acid-Insoluble Residue[8] Weight %	Acid-Insoluble Residue[8] Composition[9]
5	B	11.2	14	grayish orange, very fine crystalline dolostone	2.1	14.6	14.4	quartz, K-feldspar, smectite, illite, (limonite), (hematite)
5	B	10.8	39	light olive gray, very fine to coarse crystalline dolostone	0.6	42.8	1.4	quartz, K-feldspar, smectite, illite, (limonite), (hematite)
5	E	69.8	71	yellowish gray, very fine to fine crystalline pellet-bearing mud-intraclast-rich dolomite grainstone	0.4	9.1	4.4	quartz, illite, smectite, K-feldspar, (limonite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7]		Acid-Insoluble Residue[8]	
					Whole Rock	Insoluble Residue	Weight %	Composition[9]
5	H	54.9	37	pale red, very fine to fine crystalline mud(?)-intraclast, pellet-, and oolite-bearing calcitic dolomite boundstone, strongly dolomitized	0.4	14.8	2.7	quartz, illite, K-feldspar, smectite, (limonite), (hematite)
5	I	69.4	60	moderate yellowish brown, very fine crystalline dolocalcrete	0.5	5.6	8.9	quartz, K-feldspar, illite, (limonite), (hematite)
5	I	20.6	61	grayish orange, very fine to coarse crystalline calcitic dolostone	0.6	27.2	2.2	quartz, illite, K-feldspar, (limonite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7] Whole Rock	Weight % Organics[7] Insoluble Residue	Acid-Insoluble Residue[8] Weight %	Acid-Insoluble Residue[8] Composition[9]
-	L	212.6	81	moderate brown, silty dolostone[5]	0.1	0.2	43.1	quartz, microcline and other K-feldspars, illite (micas), smectite, vermiculite, plagioclase, kaolinite
-	L	193.2	84	white, silty crystalline dolostone[5]	0.3	1.7	18.0	quartz, smectite, K-feldspars, plagioclase, kaolinite
4	B	15.3	9	light olive gray, very fine to fine crystalline cryptalgalaminated dolomite boundstone	0.1	2.9	3.4	quartz, K-feldspar, illite, smectite, (limonite), (hematite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7] Whole Rock	Insoluble Residue	Acid-Insoluble Residue[8] Weight %	Composition[9]
4	B	11.2	8	yellowish gray, very fine to fine crystal-line cryptalga-laminated dolo-mite mudstone	0.3	5.1	5.9	quartz, smectite, illite, K-feldspar, (limonite), (hematite)
2	B	33.9	5	pale yellowish orange, very fine to medium crystalline limestone	0.6	33.4	1.8	quartz, K-feldspar, illite, (limonite), (hematite)
2	B	20.1	4	medium gray, very fine to coarse crystal-line pellet- and calcisphere-bearing cryptal-galaminated dolo-mitic lime bound-stone, partially dolomitized	0.2	12.5	1.6	quartz, illite, K-feldspar, chlorite(?), (limonite), (hematite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base of Unit (m)[4]	Sample Number	Color[6] and Rock Name	Weight % Organics[7]: Whole Rock	Weight % Organics[7]: Insoluble Residue	Acid-Insoluble Residue[8]: Weight %	Acid-Insoluble Residue[8]: Composition[9]
2	B	10.1	3	very pale orange, very fine crystalline quartz-silt-bearing algal-intraclast-rich dolomite packstone	0.5	14.7	3.4	quartz, smectite, K-feldspar, illite, (limonite), (hematite)
2	B	3.6	2	grayish yellow, silty limestone[5]	-	-	7.9	quartz, smectite, illite, K-feldspar
2	C	1.4	76	grayish yellow, very fine to fine crystalline cryptalga-laminated dolomite boundstone	1.1	25.6	4.3	K-feldspar, quartz, illite, (limonite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7]		Acid-Insoluble Residue[8]	
					Whole Rock	Insoluble Residue	Weight %	Composition[9]
2	I	46.8	56	grayish orange pink, very fine to medium crystalline algal(?) intra-clast-bearing, cryptalga-laminated dolomitic lime boundstone, partially dolomitized	0.3	6.0	5.0	quartz, plagioclase, illite, kaolinite, smectite, (limonite)
2	I	38.5	55A	light gray, very fine crystalline cryptalga-laminated lime boundstone	0.4	11.1	3.6	quartz, illite, smectite, kaolinite, unknown, (limonite), (hematite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7]: Whole Rock	Weight % Organics[7]: Insoluble Residue	Acid-Insoluble Residue[8]: Weight %	Acid-Insoluble Residue[8]: Composition[9]
2	I	32.6	49	grayish yellow, very fine to medium crystal-line algal intra-clast-rich, cryp-talgalaminated calcitic dolomite packstone, strongly dolo-mitized	0.4	30.8	1.3	quartz, illite, K-feldspar, kaolinite(?), (limonite), (hematite)
-	L	102.1	78	dark yellowish brown, very fine to fine crystal-line algal intra clast-rich dolo-mite wackestone	0.6	9.1	6.6	quartz, K-feldspar, smectite, illite (micas), (limonite), (hematite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base of Unit (m)[4]	Sample Number	Color and Rock Name[6]	Weight % Organics[7]		Acid-Insoluble Residue[8]	
					Whole Rock	Insoluble Residue	Weight %	Composition[9]
1	E	40.2	66	light olive gray, quartz-silt-, pellet-, and trilobite-bearing, echinoderm- and hyolithid-rich lime wackestone-packstone	0.5	6.8	7.4	quartz, K-feldspar, smectite, illite, (limonite), (hematite)
1	I	19.1	207	yellowish gray silty crystalline dolostone[5]	0.4	0.9	46.4	quartz, illite, smectite, K-feldspar, witherite(?), kaolinite
1	I	15.0	47	light olive gray, burrowed, pellet-, trilobite-, echinoderm-, and quartz-silt-bearing, hyolithid-rich lime wackestone-packstone	0.6	3.0	20.0	quartz, K-feldspar, illite (muscovite), unknown, (limonite), (hematite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7] Whole Rock	Weight % Organics[7] Insoluble Residue	Acid-Insoluble Residue[8] Weight %	Acid-Insoluble Residue[8] Composition[9]
1	I	12.5	46	light olive gray, very fine to very coarse crystalline pellet-, calcareous algae(?)-, and trilobite-bearing, hyolithid- and echinoderm-rich lime packstone	0.3	8.4	3.6	quartz, K-feldspar, illite, (limonite)
upper Chandler	B	35.0	31	light brown, fine to coarse crystalline laminated lime mudstone	0.6	8.8	6.8	quartz, K-feldspar, smectite, hematite, illite, (limonite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7]		Acid-Insoluble Residue[8]	
					Whole Rock	Insoluble Residue	Weight %	Composition[9]
upper Chandler	E	28.2	63	yellowish gray, very fine to very coarse crystalline oncolite-bearing dolomite boundstone	0.5	17.2	2.9	quartz, smectite, K-feldspar, illite, (limonite)
upper Chandler	E	0.0	62	very pale orange chert	-	-	-	(megacrystalline and microcrystalline quartz, dolomite, limonite, hematite, calcite)

Table 2. Continued.

Unit[2]	Measured Section[3]	Height Above Base[4] of Unit (m)	Sample Number	Color[6] and Rock Name	Weight % Organics[7] Whole Rock	Insoluble Residue	Acid-Insoluble Residue[8] Weight %	Composition[9]
upper Chandler	H	13.9	32	pale yellowish brown, very fine to very coarse crystalline oncolite-rich calcitic dolomite wackestone, strongly dolomitized	0.5	7.9	6.3	quartz, K-feldspar, illite (muscovite), smectite, (limonite), (hematite)
upper Chandler	I	20.3	43	olive gray, bored birdseye-rich pellet-bearing lime mudstone	0.1	2.3	4.4	quartz, K-feldspar, illite, kaolinite, (limonite), (hematite)
upper Chandler	I	14.5	50	dark yellowish orange chert (originally cryptalgalaminated boundstone)	-	-	-	(megacrystalline quartz, limonite, calcite)

Table 2. Continued.

[1]The weight percent of organics and acid-insoluble residue was not determined for chert samples.

[2]Units of the Giles Creek are applicable only to the Phillipson Facies. Correlative units were not recognized at section L.

[3]See Table 1 for names of measured sections and Figure 3 for section locations.

[4]Sample locations at section L are identified by their height above the base of the formation, not above the base of the unit.

[5]Sample observed in hand-specimen only. Other samples were observed both in hand-specimen and thin section. Crystal size was not determined for those samples observed in hand specimen only.

[6]Color of the fresh surface of the rock only.

[7]The weight percent of organics was not reported for samples 2, 18, and 19 (see page 7).

[8]Composition of acid-insoluble residues was determined by X-ray diffraction. Minerals are listed in order of decreasing peak heights. Minerals in parentheses were identified with a petrographic microscope, and are listed in order of decreasing relative abundance. Minerals responsible for unidentifiable peaks are present in small amounts. These peaks may result from partially crystallized, amorphous clays.

[9]Individual K-feldspars are listed if their peaks were discernible on the X-ray diffractogram. If only the major peak for the K-feldspars was discernible, these minerals are listed simply as K-feldspar.

Table 3. Color, lithology, and mineralogy of mudrock samples of the Giles Creek Formation. Mineralogy was determined by X-ray diffraction.

Unit	Section[1]	Height Above Base of Unit (m)	Sample Number	Color[2] and Lithology	Whole Rock Mineralogy[3,4]
6	J	18.3	104	pale olive dolomitic mudshale	dolomite, quartz, illite (micas), K-feldspar, kaolinite, smectite, unknown
6	B	27.7	29	reddish brown dolomitic siltstone	quartz, dolomite, smectite, illite (micas), K-feldspar, plagioclase, kaolinite, unknown
5	B	28.4	17	grayish pink dolomitic mudstone	dolomite, quartz, K-feldspar, illite (micas), plagioclase, kaolinite, unknown
5	B	16.5	16	yellowish gray mudshale	quartz, illite, K-feldspar, kaolinite
5	H	33.3	105	moderate brown dolomitic mudshale	quartz, dolomite, illite (micas), kaolinite, chlorite, microcline, anorthoclase and other K-feldspars, smectite
5	H	8.4	102	yellowish gray	quartz, K-feldspar, illite, smectite, kaolinite
4	A	35.5	98	grayish red mudshale	quartz, K-feldspar, smectite, plagioclase, kaolinite, hematite

Table 3. Continued.

Unit	Section[1]	Height Above Base of Unit (m)	Sample Number	Color[2] and Lithology	Whole Rock Mineralogy[3,4]
4	A	21.6	99	grayish red dolomitic clayshale	quartz, K-feldspar, illite, dolomite, smectite, hematite, plagioclase
4	B	40.0	11	grayish red mudshale	quartz, illite, K-feldspar, kaolinite, smectite
4	H	22.3	101	grayish red mudshale	quartz, illite (micas), K-feldspar, kaolinite, smectite, vermiculite, unknown
3	I	0.5	208	pale red calcitic mudstone	quartz, K-feldspar, illite, high-Mg calcite, kaolinite, vermiculite(?), smectite
1	M	11.8	210	yellowish gray dclomitic siltstone	dolomite, quartz, smectite, K-feldspar, illite (micas), kaolinite, plagioclase
1	W	22.0	206	light brown dolomitic mudstone	dolomite, quartz, illite (micas) K-feldspar, smectite, kaolinite
1	7km West of X	12.0	209	pale reddish brown dolomitic coarse siltstone	quartz, dolomite, K-feldspar, vermiculite(?), (muscovite, biotite), (hematite), (plagioclase), (zircon)

Table 3. Continued.

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[1]See Table 1 for names of measured sections and Figure 3 for section locations.

[2]Color of the fresh surface of the rock.

[3]Minerals are listed in order of decreasing peak heights. Minerals in parentheses were identified with a binocular microscope, and are listed in order of decreasing relative abundance. Illite and micas (muscovite and biotite) are listed together because these minerals contribute to the intensity of the same peak. Minerals responsible for unidentifiable peaks are present in small amounts. These peaks may result from partially crystallized, amorphous clays.

[4]Minerals in parentheses in sample 209 were identified with a petrographic microscope.

Table 4. Classification of carbonate rocks (from Dunham, 1962).

<table>
<tr><td colspan="4">DEPOSITIONAL TEXTURE RECOGNIZABLE</td><td rowspan="5">Original components were bound together during deposition</td><td rowspan="5">DEPOSITIONAL TEXTURE NOT RECOGNIZABLE

(Subdivided according to a classification designed to bear on physical texture or diagenesis)</td></tr>
<tr><td colspan="4">Components not bound together during deposition</td></tr>
<tr><td colspan="3">Contains mud
(clay and fine silt sizes)</td><td rowspan="3">Lacks mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>Less than 10% grains</td><td>More than 10% grains</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td><td>Crystalline limestone or dolostone</td></tr>
</table>

Table 5. Classification of carbonate rocks (from Powers, 1962).

		ORIGINAL TEXTURE NOT VISIBLY ALTERED (except by cementation)						ORIGINAL TEXTURE ALTERED					ORIGINAL TEXTURE OBLITERATED
		ORIGINAL PARTICLE TYPE						MODERATELY		STRONGLY			
		MORE THAN 25% SKELETAL[2] REMAINS	MORE THAN 25% AGGREGATE[3] GRAINS	MORE THAN 25% OOLITHS	MORE THAN 25% DETRITUS[4] FROM OLDER LS	10-50% NONCARBONATE SAND	10-50% NONCARBONATE MUD	WEAKLY DEVELOPED CALCITE MOSAIC (<10% DOLOMITE)	MORE THAN 10% DISCRETE DOLOMITE RHOMBS	STRONGLY DEVELOPED CALCITE MOSAIC (<10% DOLOMITE)	25-75% INTERLOCKING DOLOMITE	MORE THAN 75% DOLOMITE WITH RELIC TEXTURE	MORE THAN 75% DOLOMITE
ORIGINAL TEXTURE	**APHANITIC LIMESTONE** (Lime mud with less than 10% sand- or gravel-size clastic carbonate grains.) Pl. 6, fig 1	Origin of mud-size particles generally indeterminate (chalk)				*Sandy*	(marl) *Impure*	*Partially recrystallized* Pl. 7, fig. 2	*Partially dolomitized* Pl. 7, fig. 1	*Strongly recrystallized* Pl. 7, fig. 4	*Strongly dolomitized* Pl. 7, fig. 3	*Aphanitic* dolomite	**CRYSTALLINE DOLOMITE** Pl. 7, fig. 6 Where recrystallization (not involving dolomite) obliterates original texture, rock is formed **CRYSTALLINE LIMESTONE**
	CALCARENITIC LIMESTONE (More than 10% sand- or gravel-size clastic carbonate grains set in more than 10% original mud-size matrix) Pl 6, fig 2	*Skeletal*[2] calcarenitic limestone	*Aggregate*[3] calcarenitic limestone Pl 2, figs 2,4	*Oolite* calcarenitic limestone	*Detrital*[4] calcarenitic limestone							*Calcarenitic* dolomite	
	CALCARENITE (Sand-size clastic carbonate grains dominant; contains less than 10% original mud-size matrix.) Pl 6, fig 3	*Skeletal* calcarenite Pl. 1, fig 1	*Aggregate* calcarenite Pl 2, figs 1,3	*Oolite* calcarenite Pl. 2, fig 6	*Detrital* calcarenite							*Calcarenite* dolomite Pl. 7, fig. 5	
	COARSE CARBONATE (Gravel-size clastic carbonate grains dominant; contains less than 10% original mud-size matrix) Pl 6, fig 4	Coarse *skeletal* carbonate (coquina)	Coarse *aggregate* carbonate Pl 6, fig 4	Coarse *oolite* carbonate (pisolite)	Coarse *detrital* carbonate							*Coarse carbonate* dolomite	
	RESIDUAL ORGANIC (Rocks composed dominantly of attached reef-building organisms still in growth position)	*Residual* algae, *residual* coral, etc										*Residual organic* dolomite	

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1 Chart shows main rock groups in UNDERLINED CAPITAL LETTERS; modifiers of main rock groups in *italics*. For example sandy, oolite calcarenite or impure, partially dolomitized, foraminiferal calcarenitic ls.
2 Skeletal is used here as a general modifier; specific modifiers include: foraminiferal, crinoidal, algal, coral, etc.
3 Aggregate grain is a general term used for all discrete, penecontemporaneous, sand- and gravel-size grains formed on the sea floor by (1) the tearing-up, movement, and redeposition of fragments of semi-consolidated bottom sediment or (2) the aggregation of finer particles by cementation (Illing, 1954). Specific types are angular aggregate, pellet (rounded aggregate), faecal pellet, and algal nodule
4 The detrital carbonates contain more than 25% grains which have been (a) formed by the mechanical disintegration of older, well-consolidated limestones, (b) transported and, (c) redeposited as part of a younger sediment. Detrital grains are commonly distinguished by their inappropriate fossil content, color, lithology, etc

Table 6. Classification of mudrocks (adapted from Blatt, Middleton, Murray, 1980).

Ideal Size Definition	Field Criteria	Fissile Mudrock	Non-fissile Mudrock
$>$ 2/3 silt	Abundant silt visible with hand lens	Siltshale	Siltstone
1/3 to 2/3 silt	Feels gritty when chewed	Mudshale	Mudstone
$>$ 2/3 clay	Feels smooth when chewed	Clayshale	Claystone

Appendix C. Plates

Plate 1. Oncolite-rich lime grainstone, Marker "B," upper Chandler Formation, South Ross River section. Pencil for scale.

Plate 2. Planar continuous replacement of cryptalgalaminae by chert, Marker "E," Unit 2, Yam Creek section. Hammer for scale.

Plate 3. Photomicrograph of birdseye structure in lime mudstone, upper Chandler Formation, Surprise anticline section. Birdseye structure is indicative of early cementation of the rock. Crossed nicols, 20x, width of view 6.5 mm. Unstained portion of rock. Top of photomicrograph is stratigraphically "up."

Plate 4. Photomicrograph of vertical borings in lime mudstone, upper Chandler Formation, Surprise anticline section. Note penetration of lime mud and birdseye structure, indicative of early cementation of the rock. Crossed nicols, 20x, width of view 6.5 mm. Unstained portion of rock. Top of photomicrograph is stratigraphically "up."

Plate 5. Grouped ripples with medium-angle, bottom-tangent cross-stratification and a nonerosional planar base, Unit B, South Fergusson section. Now dolomite mudstone. Five-cent piece for scale.

Plate 6. Cubic and hopper-shaped halite molds in dolomite mudstone, Unit 6, Phillipson syncline section. Five-cent piece for scale.

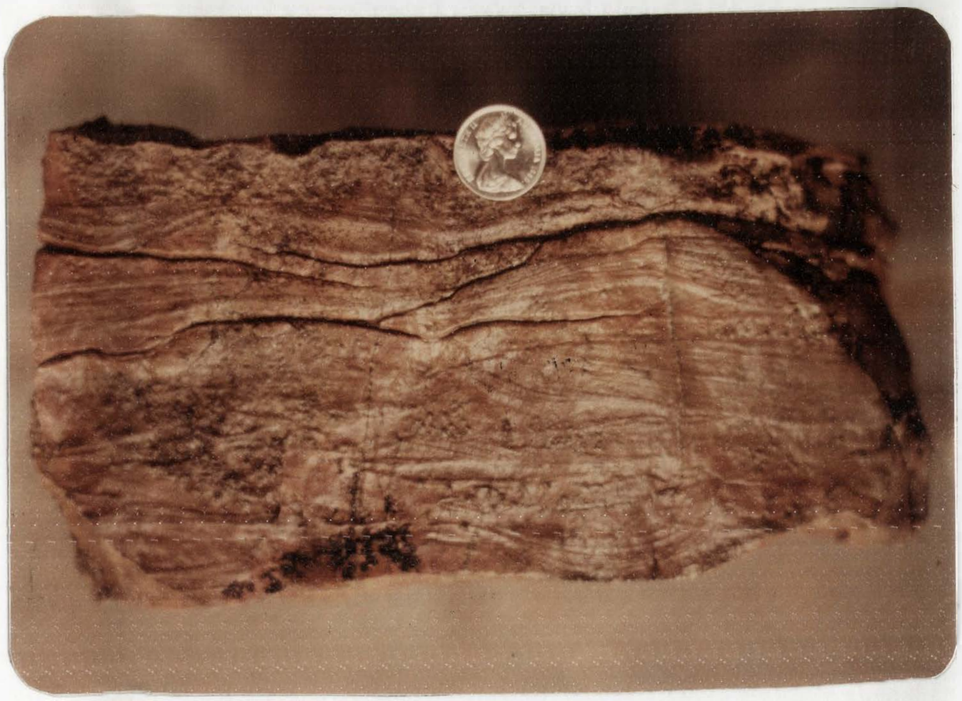


Plate 7. Grouped ripples with low-angle bottom-tangent cross-stratification and an erosional, cylindrical to scoop-shaped base, Giles Creek Formation, Southwest Ross River section. Now dolomite mudstone. Ten-cent piece for scale.

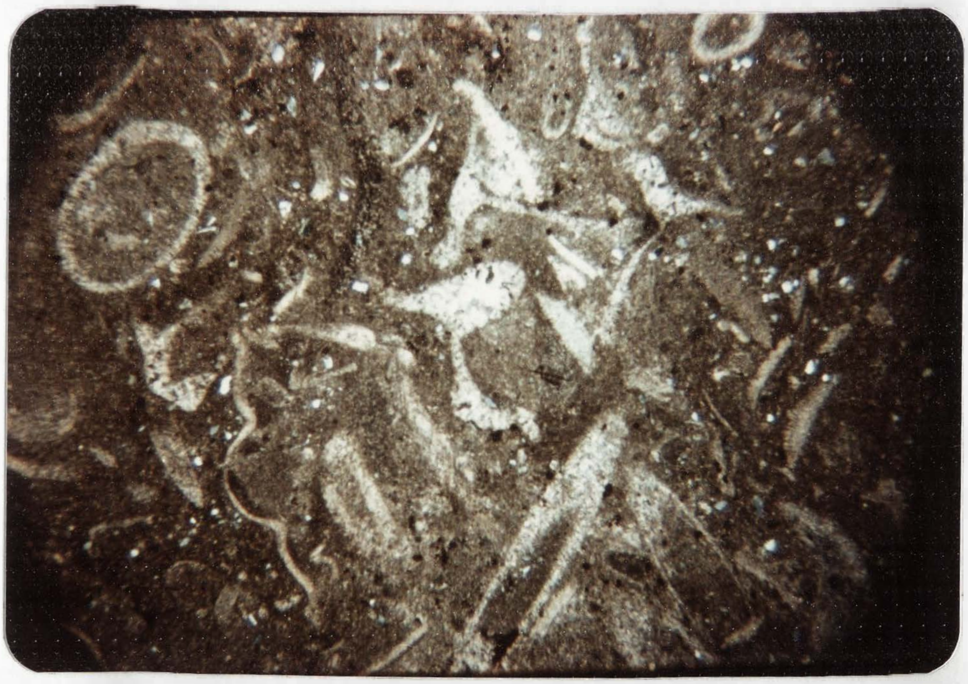


Plate 8. Photomicrograph of fossiliferous lime packstone, Unit 1, Surprise anticline section. Longitudinal (lower right) and transverse (upper left) sections of hyolithids and a transverse section of a trilobite (lower left). Crossed nicols, 20x, width of view 6.5mm. Unstained portion of rock. Top of photomicrograph is stratigraphically "up."

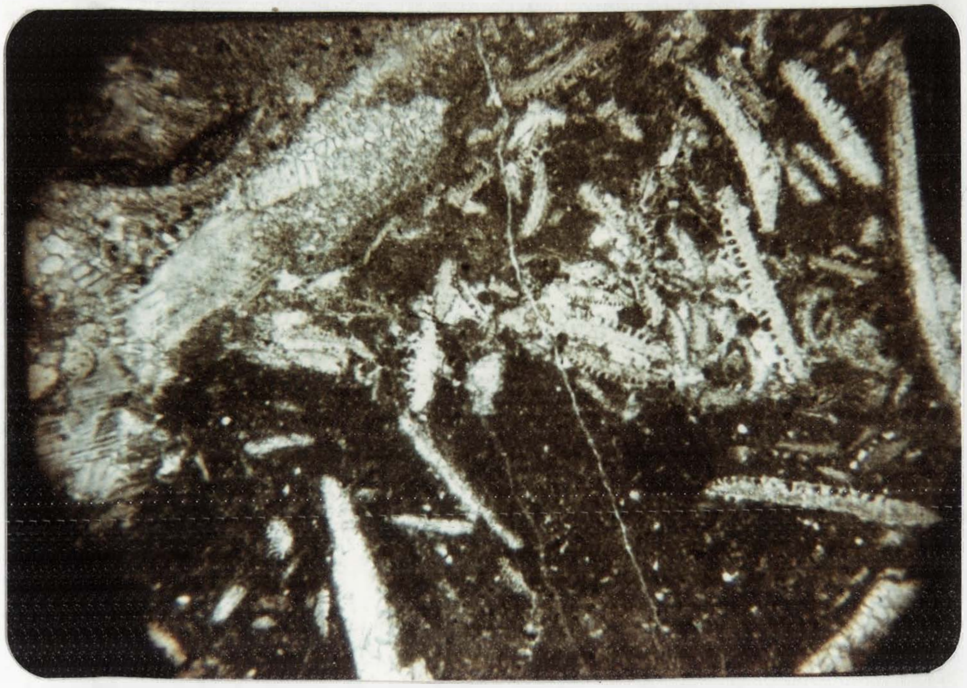


Plate 9. Photomicrograph of echinoderm plates in lime mudstone, Unit 1, Phillipson syncline section. Plane light, 20x, width of view 6.5 mm. Unstained portion of rock. Top of photomicrograph is stratigraphically "up."

Plate 10. Smooth-laminated small and medium domal stromatolites, Unit 2, Yam Creek section. Note vertical gradation from medium to small domal stromatolites. Marking pen for scale.

Plate 11. Smooth-laminated, nonbranching columnar stromatolites, Unit 2, Teresa anticline section. Ten-cent piece for scale.

Plate 12. Pseudomorphs of calcite after anhydrite, Unit 4, Ulta Bank Creek section. Five-cent piece for scale.

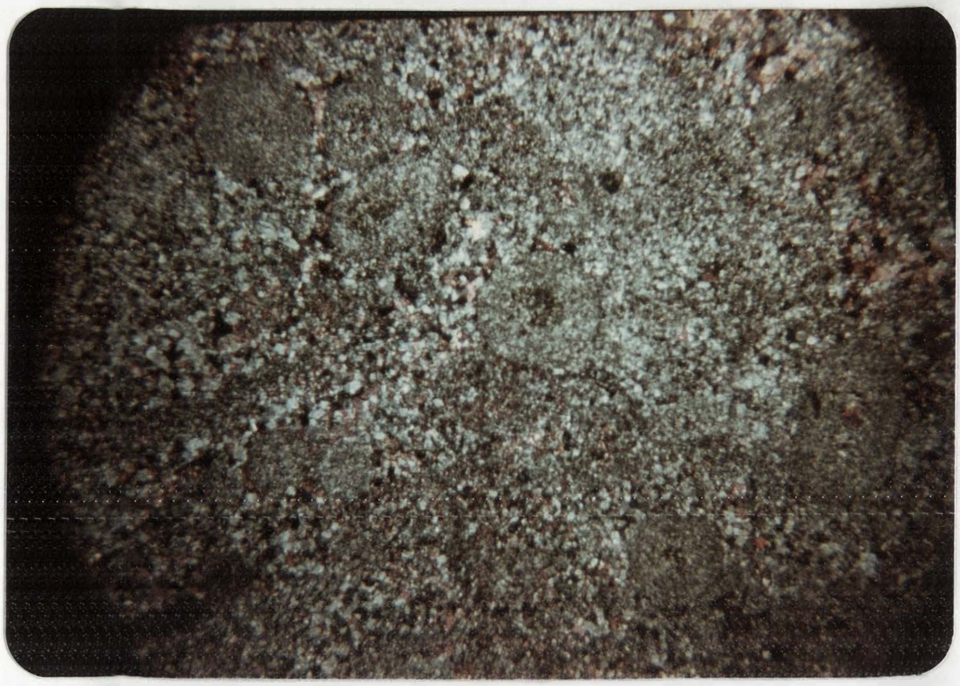


Plate 13. Photomicrograph of ooids in calcitic dolomite boundstone, Unit 5, Yam Creek section. Note opaque minerals in ooid centers. The oxides formed by alteration of pyrite which probably precipitated in locally reducing environments around entrapped organic matter. Crossed nicols, 20x, width of view 6.5 mm. Stained portion of rock. Top of photomicrograph is stratigraphically "up."

Plate 14. Dolocalcrete, Unit 5, Surprise anticline section. Note lithiclasts (top).

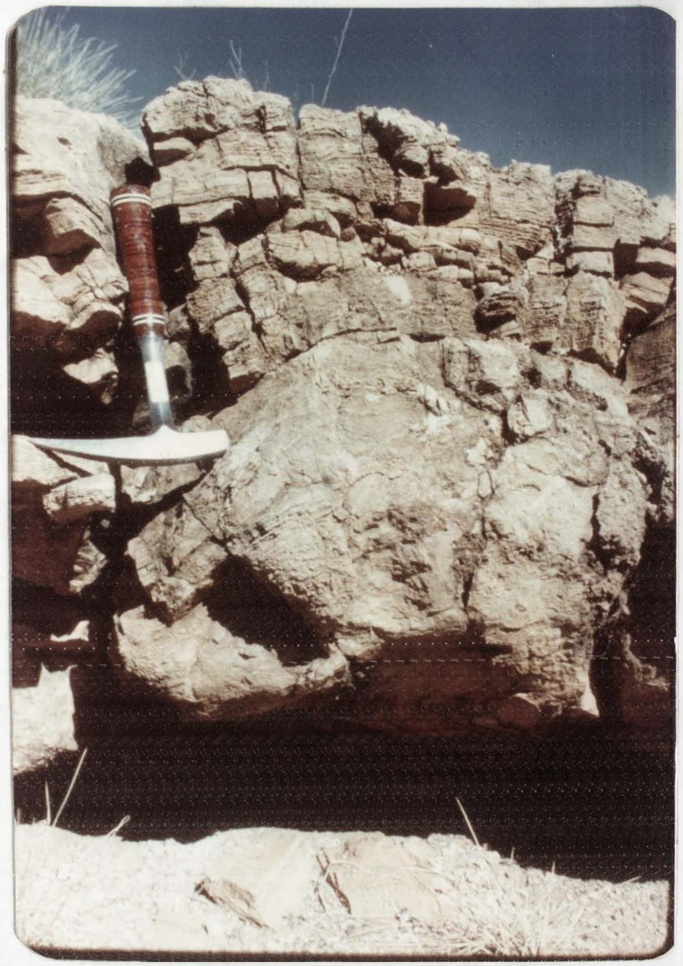


Plate 15. Smooth-laminated large domal stromatolite, Unit 5, Yam Creek section. Note cracked and fragmented cryptalgalaminae in dome center, possibly a result of desiccation. Hammer for scale.

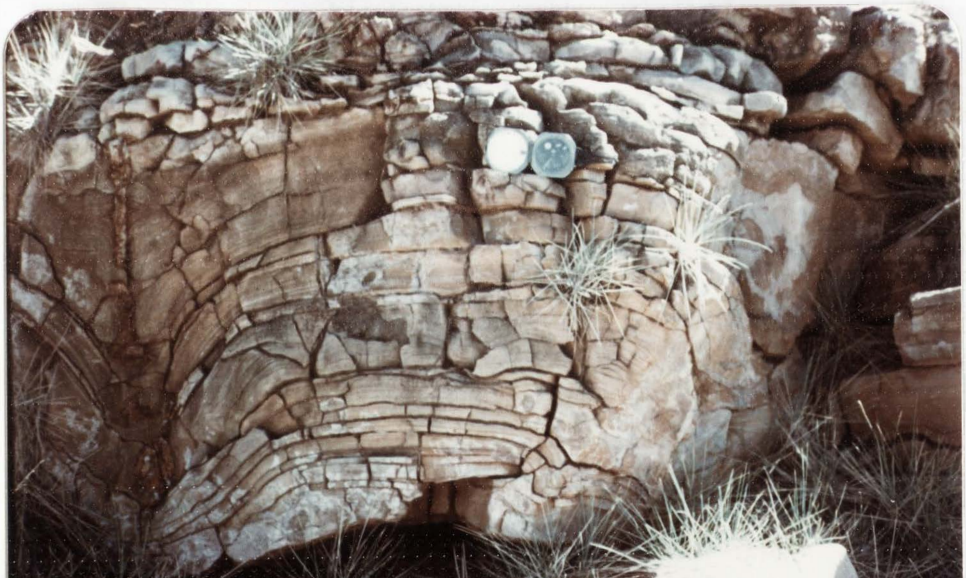


Plate 16. Smooth-laminated very large domal stromatolites, Unit 6, North Teresa section. Note chert replacement between domes (left). Brunton compass for scale.

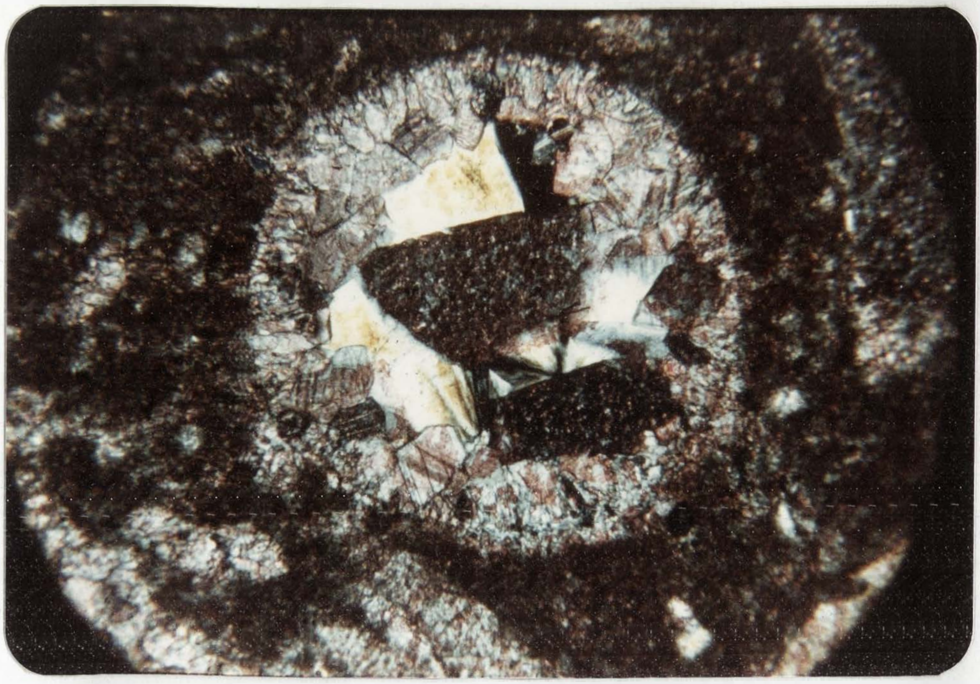


Plate 17. Photomicrograph of void in recrystallized hyolithid center filled with calcite, length-fast chalcedony, and megacrystalline quartz, Unit 1, Phillipson syncline section. Crossed nicols, 80x, width of view 1.75 mm. Stained portion of rock. Top of photomicrograph is stratigraphically "up."

Plate 18. Photomicrograph of stylolite in crystalline dolostone, upper Chandler Formation, Yam Creek section. Stylolites require pressure solution of carbonates. Note concentration of opaque oxide minerals along stylolite. Crossed nicols, 80x, width of view 1.75 mm. Stained portion of rock. Top of photomicrograph is stratigraphically "up."

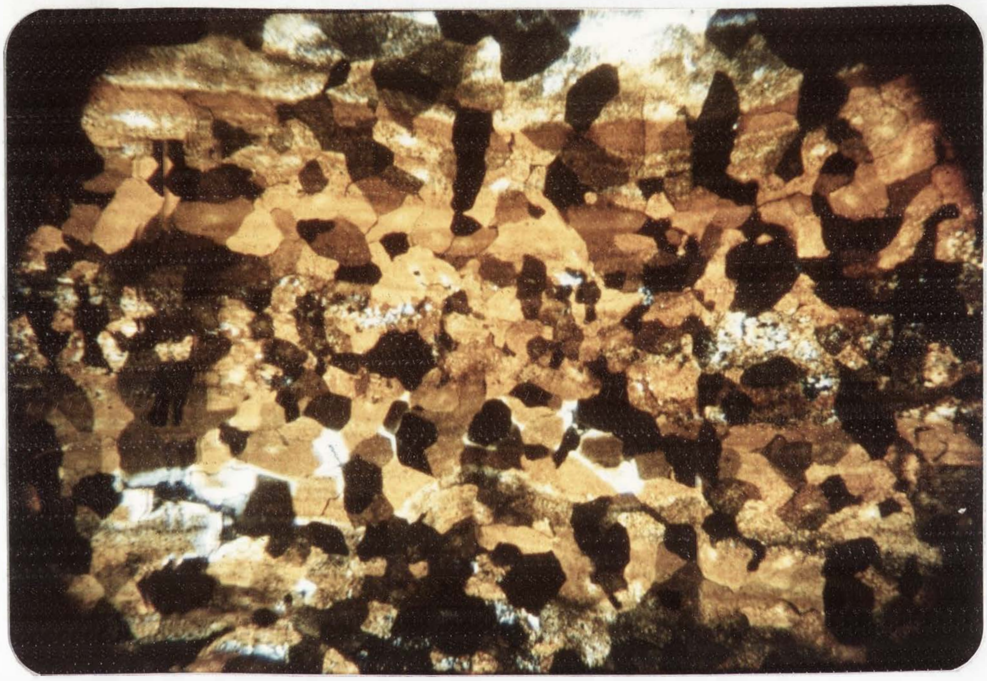
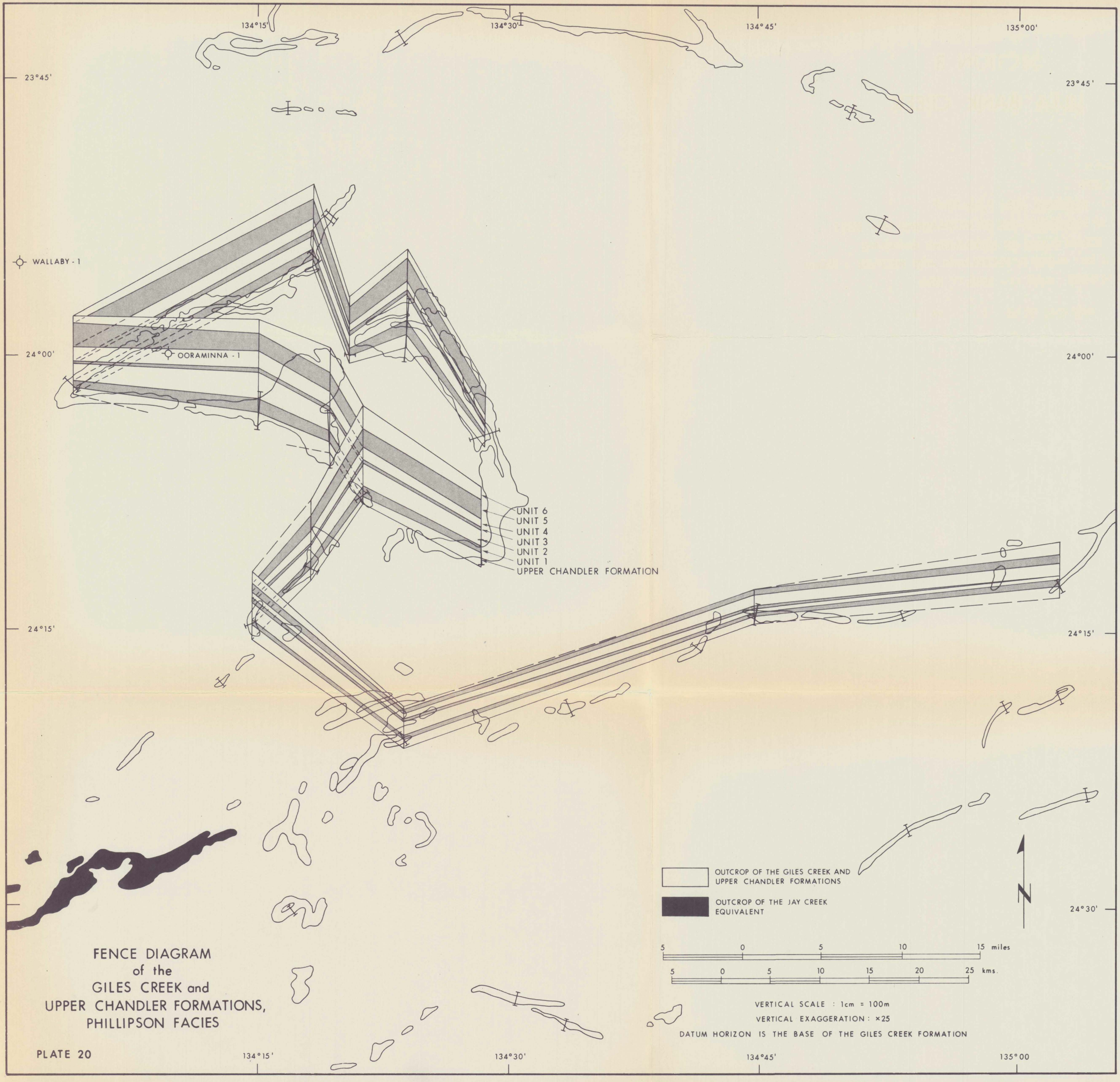


Plate 19. Photomicrograph of cryptalgalaminated boundstone replaced by megacrystalline quartz, upper Chandler Formation, Surprise anticline section. Note relict pustular laminae (bottom center). Inclusion of disseminated hematite in quartz imparts the orange color to the rock. (Crossed nicols, 20x, width of view 6.5 mm. Top of photograph is stratigraphically "up."



FENCE DIAGRAM
of the
GILES CREEK and
UPPER CHANDLER FORMATIONS,
PHILLIPSON FACIES

PLATE 20

SECTION B

ULTA BANK CREEK

LATITUDE : 24°03'07" SOUTH
LONGITUDE : 134° 15' 06" EAST
1950 AIR PHOTO REFERENCE : RODINGA RUN 2, No.5097
GEOGRAPHIC LOCATION : 10 KILOMETERS ESE OF OORAMINNA No.1 WELL
STRUCTURAL LOCATION : SOUTH FLANK OF OORAMINNA ANTICLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND MICHAEL J. STONE
DATE MEASURED AND DESCRIBED : JUNE 11 – JUNE 17, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

- LIMESTONE
- DOLOMITIC LIMESTONE
- SILTY LIMESTONE
- SANDY LIMESTONE
- LIMESTONE WITH BIRDSEYE STRUCTURE
- SILICIFIED LIMESTONE
- DOLOSTONE
- CALCITIC DOLOSTONE
- SILTY DOLOSTONE
- SANDY DOLOSTONE
- SILTSHALE , MUDSHALE
- DOLOMITIC SILTSHALE , MUDSHALE
- SILTSTONE
- CALCITIC SILTSTONE
- DOLOMITIC SILTSTONE
- MUDSTONE
- CALCITIC MUDSTONE
- CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION (GODDARD, 1963)

ULTA BANK CREEK

SECTION C
WEST TODD RIVER

LATITUDE : 23°54'50" SOUTH
LONGITUDE : 134° 18' 24" EAST
1950 AIR PHOTO REFERENCE : ALICE SPRINGS RUN 14, No. 5211
GEOGRAPHIC LOCATION : 17 KILOMETERS WSW OF TODD RIVER HOMESTEAD
STRUCTURAL LOCATION : NORTHWEST FLANK OF TODD RIVER ANTICLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND PETER D. KOTZ
DATE MEASURED AND DESCRIBED : AUGUST 10 – 12, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

LIMESTONE	SANDY DOLOSTONE
DOLOMITIC LIMESTONE	SILTSHALE , MUDSHALE
SILTY LIMESTONE	DOLOMITIC SILTSHALE, MUDSHALE
SANDY LIMESTONE	SILTSTONE
LIMESTONE WITH BIRDSEYE STRUCTURE	CALCITIC SILTSTONE
SILICIFIED LIMESTONE	DOLOMITIC SILTSTONE
DOLOSTONE	MUDSTONE
CALCITIC DOLOSTONE	CALCITIC MUDSTONE
SILTY DOLOSTONE	CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION (GODDARD, 1963)

WEST TODD RIVER

SECTION E

PHILLIPSON SYNCLINE

LATITUDE : 23° 58' 50" SOUTH
LONGITUDE : 134° 23' 52" EAST
1950 AIR PHOTO REFERENCE : RODINGA RUN 1, No. 5062
GEOGRAPHIC LOCATION : 13 KILOMETERS SSW OF TODD RIVER HOMESTEAD
STRUCTURAL LOCATION : AXIS OF PHILLIPSON SYNCLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND PETER D. KOTZ
DATE MEASURED AND DESCRIBED : JULY 21 – JULY 26, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

LIMESTONE	SANDY DOLOSTONE
DOLOMITIC LIMESTONE	SILTSHALE, MUDSHALE
SILTY LIMESTONE	DOLOMITIC SILTSHALE, MUDSHALE
SANDY LIMESTONE	SILTSTONE
LIMESTONE WITH BIRDSEYE STRUCTURE	CALCITIC SILTSTONE
SILICIFIED LIMESTONE	DOLOMITIC SILTSTONE
DOLOSTONE	MUDSTONE
CALCITIC DOLOSTONE	CALCITIC MUDSTONE
SILTY DOLOSTONE	CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION (GODDARD, 1963)

PHILLIPSON SYNCLINE

SECTION G

SOUTH BRUMBY

LATITUDE : 24° 10' 55" SOUTH
LONGITUDE : 134° 28' 34" EAST
1950 AIR PHOTO REFERENCE : RODINGA RUN 3, No. 5138
GEOGRAPHIC LOCATION : 8·5 KILOMETERS ESE OF SANTA TERESA ABORIGINAL SETTLEMENT
STRUCTURAL LOCATION : SOUTHWEST FLANK OF ALLAMBARINJA SYNCLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND PETER D. KOTZ
DATE MEASURED AND DESCRIBED : JULY 27 – JULY 30, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

LIMESTONE	SANDY DOLOSTONE
DOLOMITIC LIMESTONE	SILTSHALE, MUDSHALE
SILTY LIMESTONE	DOLOMITIC SILTSHALE, MUDSHALE
SANDY LIMESTONE	SILTSTONE
LIMESTONE WITH BIRDSEYE STRUCTURE	CALCITIC SILTSTONE
SILICIFIED LIMESTONE	DOLOMITIC SILTSTONE
DOLOSTONE	MUDSTONE
CALCITIC DOLOSTONE	CALCITIC MUDSTONE
SILTY DOLOSTONE	CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS
USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION
(GODDARD, 1963)

SECTION H

YAM CREEK

LATITUDE : 24°04'34" SOUTH
LONGITUDE : 134° 19'17" EAST
1950 AIR PHOTO REFERENCE : RODINGA RUN 2, No. 5098
GEOGRAPHIC LOCATION : 10 KILOMETERS NNW OF SANTA TERESA ABORIGINAL SETTLEMENT
STRUCTURAL LOCATION : EAST FLANK OF YAM CREEK ANTICLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND MICHAEL J. STONE
DATE MEASURED AND DESCRIBED : JUNE 18 - JUNE 26, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

- LIMESTONE
- DOLOMITIC LIMESTONE
- SILTY LIMESTONE
- SANDY LIMESTONE
- LIMESTONE WITH BIRDSEYE STRUCTURE
- SILICIFIED LIMESTONE
- DOLOSTONE
- CALCITIC DOLOSTONE
- SILTY DOLOSTONE
- SANDY DOLOSTONE
- SILTSHALE, MUDSHALE
- DOLOMITIC SILTSHALE, MUDSHALE
- SILTSTONE
- CALCITIC SILTSTONE
- DOLOMITIC SILTSTONE
- MUDSTONE
- CALCITIC MUDSTONE
- CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS
USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION
(GODDARD, 1963)

YAM CREEK

SECTION I

SURPRISE ANTICLINE

LATITUDE : 24° 07' 48" SOUTH
LONGITUDE : 134° 21' 17" EAST
1950 AIR PHOTO REFERENCE : RODINGA RUN 3, No. 5141
GEOGRAPHIC LOCATION : 3·5 KILOMETERS NNW OF SANTA TERESA ABORIGINAL SETTLEMENT
STRUCTURAL LOCATION : AXIS OF SURPRISE ANTICLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND MICHAEL J. STONE
DATE MEASURED AND DESCRIBED : JUNE 31 – JULY 5, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

- LIMESTONE
- DOLOMITIC LIMESTONE
- SILTY LIMESTONE
- SANDY LIMESTONE
- LIMESTONE WITH BIRDSEYE STRUCTURE
- SILICIFIED LIMESTONE
- DOLOSTONE
- CALCITIC DOLOSTONE
- SILTY DOLOSTONE
- SANDY DOLOSTONE
- SILTSHALE , MUDSHALE
- DOLOMITIC SILTSHALE , MUDSHALE
- SILTSTONE
- CALCITIC SILTSTONE
- DOLOMITIC SILTSTONE
- MUDSTONE
- CALCITIC MUDSTONE
- CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS
USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION
(GODDARD, 1963)

SURPRISE ANTICLINE

SECTION J

NORTH TERESA

LATITUDE : 24°11'48" SOUTH
LONGITUDE : 134°18'12" EAST
1950 AIR PHOTO REFERENCE : RODINGA RUN 4, No. 5016
GEOGRAPHIC LOCATION : 9 KILOMETERS SW OF SANTA TERESA ABORIGINAL SETTLEMENT
STRUCTURAL LOCATION : NORTHWEST FLANK OF TERESA ANTICLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND PETER D. KOTZ
DATE MEASURED AND DESCRIBED : JULY 6 – JULY 10, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

LIMESTONE
DOLOMITIC LIMESTONE
SILTY LIMESTONE
SANDY LIMESTONE
LIMESTONE WITH BIRDSEYE STRUCTURE
SILICIFIED LIMESTONE
DOLOSTONE
CALCITIC DOLOSTONE
SILTY DOLOSTONE
SANDY DOLOSTONE
SILTSHALE, MUDSHALE
DOLOMITIC SILTSHALE, MUDSHALE
SILTSTONE
CALCITIC SILTSTONE
DOLOMITIC SILTSTONE
MUDSTONE
CALCITIC MUDSTONE
CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION (GODDARD, 1963)

NORTH TERESA

SECTION K

TERESA ANTICLINE

LATITUDE : 24°14'44" SOUTH
LONGITUDE : 134°14'49" EAST
1950 AIR PHOTO REFERENCE : RODINGA RUN 5, No. 5064
GEOGRAPHIC LOCATION : 15 KILOMETERS NE OF DEEP WELL HOMESTEAD
STRUCTURAL LOCATION : AXIS OF TERESA ANTICLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND PETER D. KOTZ
DATE MEASURED AND DESCRIBED : JULY 12 – JULY 14, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

LIMESTONE	SANDY DOLOSTONE
DOLOMITIC LIMESTONE	SILTSHALE, MUDSHALE
SILTY LIMESTONE	DOLOMITIC SILTSHALE, MUDSHALE
SANDY LIMESTONE	SILTSTONE
LIMESTONE WITH BIRDSEYE STRUCTURE	CALCITIC SILTSTONE
SILICIFIED LIMESTONE	DOLOMITIC SILTSTONE
DOLOSTONE	MUDSTONE
CALCITIC DOLOSTONE	CALCITIC MUDSTONE
SILTY DOLOSTONE	CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION (GODDARD, 1963)

SECTION L

SOUTH FERGUSSON

LATITUDE : 23°42'02" SOUTH
LONGITUDE : 134°30'38" EAST
1950 AIR PHOTO REFERENCE : ALICE SPRINGS RUN 11, No.5065
GEOGRAPHIC LOCATION : 11 KILOMETERS SSE OF ROSS RIVER HOMESTEAD
STRUCTURAL LOCATION : SOUTH FLANK OF FERGUSSON SYNCLINE
MEASURED AND DESCRIBED BY : JAMES A. DECKELMAN AND PETER D. KOTZ
DATE MEASURED AND DESCRIBED : AUGUST 13 - 19, 1980

VERTICAL SCALE : 1" = 10 METERS

LEGEND

LIMESTONE	SANDY DOLOSTONE
DOLOMITIC LIMESTONE	SILTSHALE , MUDSHALE
SILTY LIMESTONE	DOLOMITIC SILTSHALE, MUDSHALE
SANDY LIMESTONE	SILTSTONE
LIMESTONE WITH BIRDSEYE STRUCTURE	CALCITIC SILTSTONE
SILICIFIED LIMESTONE	DOLOMITIC SILTSTONE
DOLOSTONE	MUDSTONE
CALCITIC DOLOSTONE	CALCITIC MUDSTONE
SILTY DOLOSTONE	CONCEALED

25 • SAMPLE NUMBER (SEE TABLES 2 AND 3)
COLORS DESIGNATED WITH NUMBERS AND LETTERS USING THE MUNSELL SYSTEM OF COLOR IDENTIFICATION (GODDARD, 1963)

SOUTH FERGUSSON